GEOLOGICAL SURVEY OF GEORGIA

W. S. YEATES, State Geologist

BULLETIN No. 9—A

A Preliminary Report on a Part of the Granites and Gneisses of Georgia

BY

THOMAS L. WATSON, Ph. D.
Assistant Geologist

1902

GEO. W. HARRISON, State Printer
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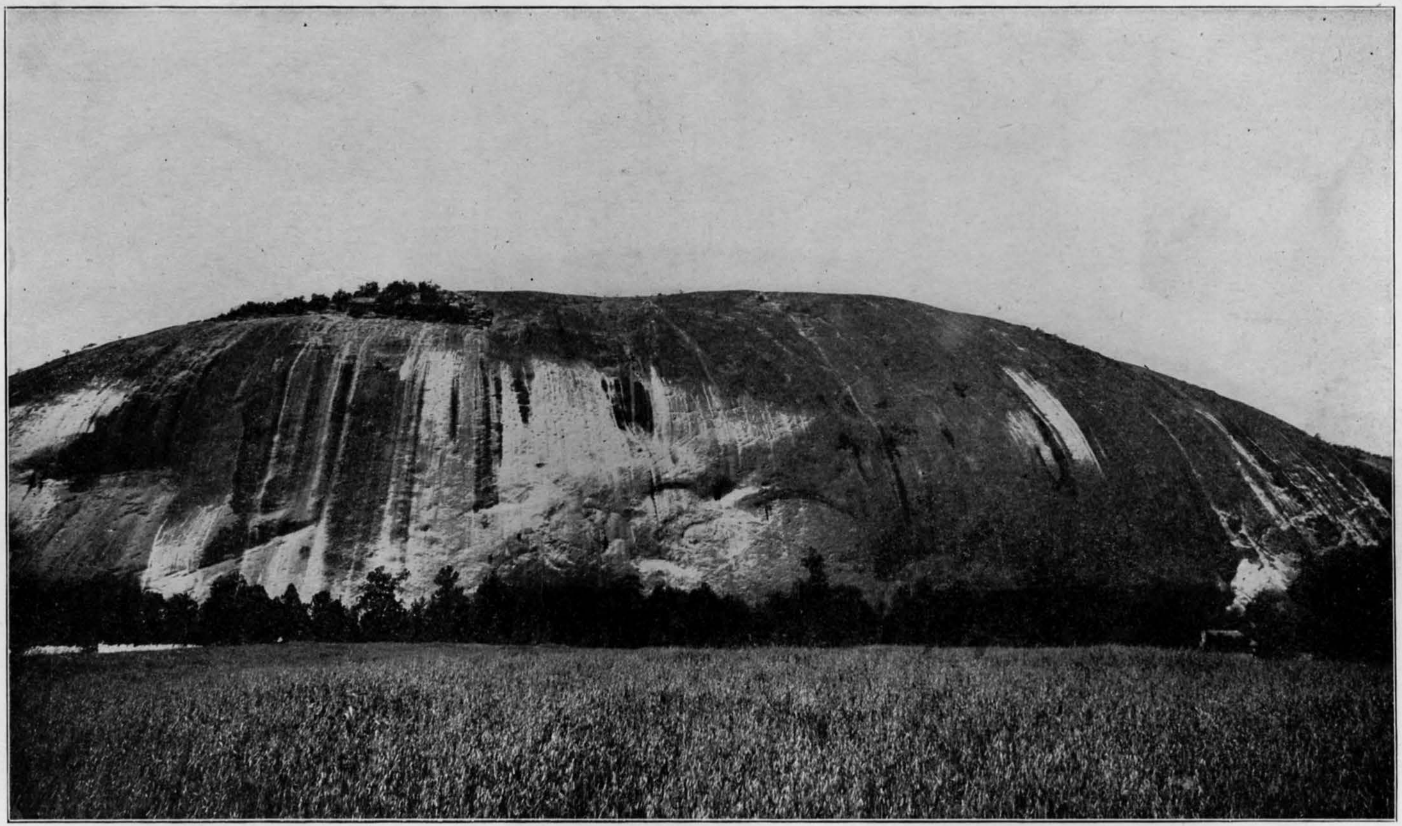

STONE MOUNTAIN, DEKALB COUNTY, GEORGIA, 16 MILES NORTHEAST OF ATLANTA, ON THE GEORGIA RAILROAD.
A GRANITE BOSS RISING 686 FEET ABOVE THE GENERAL SURFACE OF THE SURROUNDING PIEDMONT PLAIN.

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ERRATA

1 On page 26, 16th line from the bottom, for "Giekie", read *Geikie.*

2 On page 61, 4th line from the top, for "72", read *74.*

3 On page 70, 3rd line from the bottom, for "biotite granite-gneiss", read *biotite granite and granite-gneiss.*

4 On page 75, in column I, table of analyses, opposite soda, for "4.46", read *4.45;* opposite ignition, for "0.36", read *0.39;* and opposite total, for "100.85", read *100.87.*

5 On page 77, 1st line at top of page, for "the following", read *the following species.*

6 On page 83, 3rd line from the bottom, for "Itis", read *It is.*

7 On page 93, 17th line from the bottom, for "indentity", read *identity.*

8 On page 109, 23rd line from the bottom, for "map opposite page 65", read *map opposite page 88.*

9 On page 115, 1st and 6th lines from the top, the word "Hayne" should be spelt *Hanye.*

10 On page 117, 10th line from the top, the word "Hayne" should be spelt *Hanye.*

11 On page 128, 15th line from the top, for "alleys", read *valleys.*

12 On page 139, 14th line from the top, for "has", read *have.*

13 On page 218, 14th line from the top, for "44.52", read *44.61.*

14 On page 241, in column VI, table of analyses, opposite Na_2O, for "4.22", read *4.82.*

15 On page 243, table of analyses, for "XILV", read *XLIV.*

16 On page 252, 18th line from the top, for "inmicroperthitic", read *in microperthitic.*

17 On page 284, 2nd line from the bottom, for "Brauner", read *Branner;* also, in the references at the bottom of the same page, transpose references *4* and *5.*

18 On page 305, 7th line from the top, for "42.37", read *44.72;* and, 8th line from the top, for "34.66", read *37.01.*

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[1] Also known as Cedar Rock.

[1] Known also as the Watson and Brantley Quarry.

LETTER OF TRANSMITTAL

GEOLOGICAL SURVEY OF GEORGIA,
Atlanta, September 2nd, 1901.

To His Excellency, A. D. CANDLER, *Governor and President of the Advisory Board of the Geological Survey of Georgia*,

SIR:—I have the honor to transmit herewith the report of Dr. Thomas L. Watson, Assistant Geologist, on a part of the GRANITES AND GNEISSES OF GEORGIA, to be published as Bulletin No. 9–A, A Preliminary Report on a Part of the GRANITES AND GNEISSES OF GEORGIA.

As a rule, only those deposits, that have been, or are now being, worked, and those, included in the general areas, as indicated by the several maps, are included in this bulletin, other valuable deposits of these stones being left for a later report.

Very respectfully yours,
W. S. YEATES,
State Geologist.

INTRODUCTION

The present report, as the title indicates, embodies the study of only a part of the granites and gneisses of the State. Excepting the Paleozoic area, occupying the northwest portion of the State and including the ten northwestern counties, all that part of the State north of the Fall Line, which line extends from Augusta through Macon to Columbus, contains somewhat extensive areas of granitic rocks. Of this northern section, granites and gneisses have only been quarried in those counties comprised within the limits of the Piedmont plateau. Openings, of greater or less dimensions, have been made in nearly every one of the Piedmont counties, where stone of this class was desired for local purposes; but, up to the present time, less than a score of these counties include the entire granite industry in Georgia.

Owing, therefore, to the rapid increase in the production of, and output in, these rocks in the State, within the past few years, and the enormous quantity of superior stone, thoroughly suited for all grades of construction, decorative and monumental work, for which granite is used, there was an urgent demand for an immediate and thorough geologic study of the granites and gneisses, occurring in the principal granite-producing counties. This report, then, is limited to a study of the granitic rocks of the principal granite-producing counties in Piedmont Georgia. Many counties, not here included, contain, in all probability, equally as large areas of granite and gneiss, as the ones reported on; and these will furnish material for a second volume on this most important subject.

The report is divided into, and treated in, six chapters. Chapter I discusses the physical and chemical properties, varieties, geological age, mode of occurrence, history and uses, and origin of granites in general; also, the general geological and geographical distribution of granites in the United States, with special reference to those of the Atlantic Border region. Chapter II treats of the general physical, chemical and economic properties of building stones, as relating more especially to granitic rocks. In the preparation of this part of the report, free and liberal use has been made of the following valuable publications, bearing on the subject, namely: "Stones for Building and Decoration," by George P. Merrill; "The Physical, Chemical and Economic Properties of Building Stones," by George P. Merrill; and "Building and Ornamental Stones of Wisconsin," by E. R. Buckley. All references to other publications used are made in the text.

In Chapter III, Part 1, the general geology and physiography of the Georgia portion of the Piedmont plateau is described. Part 2 gives a general detailed description of the individual properties by counties, including the occurrence, the chemical and mineral compositions, and the physical tests, of the Georgia granitic rocks.

Chapter IV includes the general study of the chemic and lithologic characteristics and the correlation of the Georgia granitic rocks.

Chapter V, Part 1, contains a statement and discussion of the general principles of rock-weathering. In the preparation of this part of the report, unlimited use was made of the published papers on this subject, by Dr. Merrill, in the "Journal of Geology", and the "Bulletin of the Geological Society of America"; and in his book, entitled "Rocks, Rock-Weathering and Soils". Part 2 of Chapter V, contains a detailed study of the changes and processes, involved in passing from fresh to decayed rock (weathering) as especially applicable first, to the granites; second, to the porphyritic granites; and third, to the granite-gneisses, occurring in Georgia.

Chapter VI concludes with tables of statistics, physical tests and chemical analyses of the Georgia granitic rocks.

The map accompanying this report, on which is delineated the areas of granite and gneiss, does not include all the areas of these rocks in the State; but only the areas, studied by the writer in the field and described in the text, are shown. A similar detailed field-study of the remaining counties, which contain granites and similar rocks, will, of course, add to the areas given on the map, and will likely result in the extension of those here studied. The writer has made a reconnaissance of several granite areas not shown on the map; but he has not attempted to give them, for the reason, that they have not been studied in sufficient detail and their boundaries accurately enough traced in the field to warrant their mapping. The same convention or color is used to denote both the granites and gneisses, for the reason that the gneisses studied and reported on in this volume are believed to be true granite-gneisses, i. e., derived from original intrusive granites.

In each one of the areas designated on the map, numerous small openings have been made in different places, and some rock taken out for purely local purposes. Such openings are exceedingly small as a rule, and could not be dignified by the name of quarry. These openings have not, therefore, been marked on the map. Only those, which are properly termed quarries, are given.

THE

Granites and Gneisses of Georgia

CHAPTER I

GENERAL CONSIDERATIONS

DEFINITION. — The exact origin of the term, granite, is somewhat obscure. It is probably derived, however, from the Latin word, *granum*, meaning a grain, in reference to its granular texture. Edward Hull[1] refers to its use by Caesalpinus, as far back as the year 1596, and, again, in 1698, in a publication by Pitton de Tournefort. It was used by Werner,[2] in studying the rocks of the Hartz mountains in 1775, and, ten years later, by Hutton[3] (1785), when in search for facts in proof of the igneous origin of this rock. The name is also stated, to have been traced by Chateau to the Italian word, *granito*, in reference to the different colored grains. The exact usage in the above cases is not entirely clear; but it evidently related to rock texture and not to mineral composition, as it was apparently employed to designate rocks of a coarsely granular character.

Whatever its derivation and usage then, it is employed by petrographers, at present, to designate any *holo*-crystalline, massive, granular rock, of igneous origin, composed of the two essential minerals, quartz and a potash feldspar, either orthoclase or microcline, or both. Usually, one or more minerals of the mica, amphibole or pyroxene groups are present, to the extent of imparting

1 A Treatise on Building and Ornamental Stones, London, 1872, p. 20.

2 Lyell's Principles of Geology, 1883, 11th Ed., Vol. I, p. 69.

3 Ibid., p. 74.

some distinctive character to the rock. Each of these is evident to the eye without the aid of a lens. More or less plagioclase feldspar is invariably present, with numerous other minerals, in microscopic proportions, which do not in any degree influence the character or properties of the rock.

MINERAL COMPOSITION AND STRUCTURE. — Prestwich[1] quotes from Delesse the following proportion of the various mineral constituents, determined for two well known granites :—

Egyptian Red Granite

	Parts
Orthoclase Feldspar, Red	43
Albite " White	9
Quartz, Gray	44
Mica, Black	4
Total	100

Porphyritic Granite, Vosges

	Parts
Orthoclase Feldspar, White	28
Oligoclase " Reddish	7
Quartz, Gray	59
Mica	6
Total	100

In addition to the two essential minerals, quartz and a potash feldspar (orthoclase or microcline), more or less plagioclase feldspar, generally albite or oligoclase, and the characterizing accessory mineral or minerals, belonging to the ferro-magnesian group, mica, pyroxene or hornblende, occur. Other accessories are found in microscopic proportions, the most common of which are apatite, zircon and magnetite, with less frequently sphene, topaz, garnet, epidote, pyrite, allanite, beryl, tourmaline and flourite. These minerals oftentimes prove to be of scientific interest; but they are not of any importance economically; since they rarely exert any direct influence, either on the appearance or the wearing qualities of the rock.

The constituent minerals forming any igneous rock-mass are conveniently divisible into (a) *essential* and (b) *accessory* minerals. These are further divisible, according to whether they are the first products of consolidation from the parent mass, or are products of subsequent changes into (c) *primary* or *original*, and (d) *secondary* minerals.

[1] Chemical and Physical Geology, Vol. I., p. 42.

The *essential* constituents of a rock are those minerals, which are requisite and necessary, for the rock to retain its name. For example, when the essential mineral, quartz, is absent from the granite magma, or is present only to the extent of an accessory, the rock is called a syenite. The *accessory* constituents are those minerals, whose presence or absence do not affect the name of the rock: to wit, the presence of magnetite in granite. The accessory mineral, predominating in the rock, and as a rule, present in such quantity as to be recognizable by the unaided eye, is termed the *characterizing* accessory. Thus, biotite granite (granitite) is composed of the essential minerals, quartz and a potash feldspar, and with enough of the accessory mineral, biotite, present, to impart a distinctive character. *Primary* or *original* constituents are those, formed upon the first consolidation of the rock from its parent molten magma. All the essential constituents are primary or original; but, conversely, not all the primary constituents are essential ones. Thus, quartz and potash feldspar are both primary and essential minerals in a granite, while magnetite and apatite are primary, though not essential. *Secondary* mineral constituents are those, which have formed, subsequent to the rock's first consolidation from the molten magma, and are traceable directly to the agencies of weathering and alteration. For example, the change of biotite into the secondary product, chlorite, in a granite.

A list of the most important minerals, occurring in granites, arranged according to the above, is given below:—

CONSTITUENTS OF GRANITES[1]

Essential Minerals

Quartz	
Orthoclase	FELDSPAR GROUP
Microcline	FELDSPAR GROUP
Albite	FELDSPAR GROUP
Oligoclase	FELDSPAR GROUP
Labradorite	FELDSPAR GROUP

[1] The Building Stones of the United States and Statistics of the Quarry Industry, by G. W. Hawes (Geo. P. Merrill, Editor), Tenth Census Rept., 1880, Vol. X, p. 16.

Accessory Minerals

Characterizing Accessories		Microscopic Accessories
Muscovite	Mica Group	Sphene
Biotite	Mica Group	Zircon
Phlogopite	Mica Group	Garnet
Lepidolite	Mica Group	Danalite
Hornblende		Rutile
Pyroxene		Apatite
Epidote		Pyrite
Tourmaline		Pyrrhotite
Acmite		Magnetite
		Hematite
		Ilmenite

Secondary Minerals, Due to Weathering and Alteration

Chlorite	Calcite
Epidote	Muscovite
Uralite	Limonite
Kaolin	Hematite

Magnetite

Structurally, the granites are holo-crystalline, granular rocks; and, as a rule, without perfect crystal outline (*allotriomorphic*) displayed in the essential minerals. The feldspars, however, approach more or less perfect (*idiomorphic*) forms at times, when the structure is referred to, as *hypidiomorphic-granular*. This irregular crystal outline of the constituent minerals (*anhedra*) has been determined by interfering crystallization, resulting in each mineral assuming the form imposed upon it by its growing neighbors. As original products of crystallization from a molten magma and interference on consolidation, the individual minerals are rendered not only irregular in crystal outline; but the grains interlock in an intricate manner, imparting thereby a high relative strength to the rock. The constituent grains vary in size from several inches down to being scarcely discernible by the naked eye.

When unchanged by metamorphism, the granites are massive rocks. Subsequent action, however, on a granitic mass chiefly through pressure and recrystallization, results oftentimes in a more or less perfect re-arrangement of the constituent minerals along parallel or wavy lines, producing a secondary structure in the mass (*schistosity*), forming the so-called granite-gneisses.

True gneisses, however, are the resulting metamorphosed recrystallized products of sedimentation, in which the original bedding planes are generally preserved.

In granites, as in many of the other igneous rocks, one or more of the minerals may stand out prominently as larger regularly or irregularly bounded crystals, imbedded in a groundmass of finer-grained crystallization. The large crystals have been conveniently designated *phenocrysts*, and are frequently quite conspicuous to the unaided eye. Such a structure among igneous rocks is known as a porphyritic one, and when developed in the granite magma, the rock is termed a porphyritic granite.

The quartz and feldspar in granite may occur so intergrown or intercrystallized in parallel positions, with coarse (*macroscopic*) texture, that when cut in certain directions the section represents a graphic appearance, and the structure is called pegmatitic or graphic, and the rock is known as *graphic granite.* The microscopic intergrowths of the two minerals, quartz and feldspar, are frequently developed in granites. This structure is referred to as *micropegmatitic* or *granophyric.*

The granites vary indefinitely in texture from fine, even granular to coarsely porphyritic types, in which the porphyritic feldspars are several inches in length. The feldspars are the only porphyritically developed mineral species in granite. The quartz porphyries, which have essentially the same mineral and chemical composition as the granites, and from which they differ mainly in structure, contain quartz as the porphyritically developed mineral. On solidification from the molten magma, quartz has been in all cases the last mineral to crystallize out; and it occurs filling more or less well defined areas and interspaces with irregular, interlocking outlines. On microscopic examination under a high-power objective, the quartz anhedra are seen to contain numerous small cavities partially or wholly filled with fluid or gas, or both, containing usually sodium and potassium salts and carbonic acid gas. Other inclusions in the form of rutile needles and prismatic apatite and zircon crystals are commonly observed. Microscopic mineral inclusions may be common to each of the essential constituents in granite.

Chemical Composition. — The chemical composition is necessarily controlled by the mineral composition of the rock, and varies accordingly within certain prescribed limits.

Some idea may be gained as to the varying composition of granites in general from the following analyses :—

KINDS AND LOCALITIES	SiO_2	Al_2O_3	FeO and Fe_2O_3	CaO	MgO	K_2O	Na_2O	H_2O or loss on Ignition
Biotite granite, near Dublin, Ireland[1]	73.00	13.64	2.44	1.84	2.11	4.21	3.53	
Biotite granite, Silesia[1]	73.13	12.49	2.58	2.40	0.27	4.13	2.61	
Biotite granite, Raleigh, N. C.[1]	69.28	17.44	2.30	2.30	0.27	2.76	3.64	
Hornblende granite, Salt Lake, Utah[1]	71.78	14.75	1.94[7]	2.36	0.71	4.89	3.12	
Hornblende granite, Sauk Rapids, Minn.[1]	64.13	21.01		6.90	1.26	1.22	3.31	
Gneissoid biotite granite, District of Columbia[1]	69.33	14.33	3.60	3.21	2.44	2.67	2.70	
Hornblende-mica granite, Syene, Egypt[1]	68.18	16.20	4.10	1.75	0.48	6.48	2.88	
Granite near Ironton, Missouri[2]	69.94	15.19	2.48	1.15	0.92	4.29	3.95	0.99[5]
Biotite granite, Woodstock, Maryland[3]	71.79	15.00	1.89	2.50	0.51	4.75	3.09	0.64[6]
Biotite granite, Dorsey Run Cut, Maryland[3]	70.45	15.98	2.59	2.60	0.77	3.59	3.83	0.45[6]
Biotite granite, near Oglesby, Georgia[4]	69.74	16.72	1.45	1.93	0.36	5.33	4.84	0.47[5]
Porphyritic granite, near Line Creek, Fayette county, Georgia[4]	70.24	16.78	1.46	2.00	0.76	5.03	3.70	0.50[5]
Muscovite granite, Stone Mountain, Georgia[8]	72.56	14.81	0.94	1.19	0.20	5.30	4.94	0.70[5]

Varying amounts of other constituents commonly occur in granitic rocks; but they are generally present in small proportions, amounting frequently to scarcely more than a trace, which may safely be omitted in the methods of ordinary analysis. Phosphoric anhydride (P_2O_5) in combination with calcium, as the mineral apatite, is almost universally present in granites, rarely exceeding 0.2 per cent., and frequently ranging as low as a few hundredths of one per cent. Titanic oxide, usually present as titaniferous magnetite, or as ilmenite, and its alteration product, leucoxene, and as included needles of rutile in the quartz, and some-

1 Quoted from Merrill, Geo. P., Rocks, Rock-Weathering and Soils, 1897, p. 66.

2 Haworth, E., The Crystalline Rocks of Missouri, Ann. Rep., Missouri Geol. Survey, 1894, Vol. VIII, p. 140. Contains, in addition, 0.03 MnO; 0.13 P_2O_5; 0.25 TiO_2.

3 Williams, G. H., 15th Ann. Rep., U. S. G. S., 1893–94, p. 672.

4 Watson, Thomas L., Analyst.

5 Loss on Ignition.

6 Water.

7 Gave 1.09 per cent. of manganese oxide.

8 R. L. Packard, Analyst.

times replacing silica to a slight degree in the ferro-magnesian group of silicates (mica, hornblende and pyroxene), amounts to as much as 0.50 per cent., rarely more and generally less. Manganese is frequently present in small and variable amounts. Barium, strontium and lithium, while common, never occur except in traces of less than 0.10 per cent. Zirconium, present as the mineral zircon, is very prevalent; but in scarcely more than traceable quantities. Owing to the large amount of free quartz added to that, present in the form of the silicates, granite is grouped as the most acid member of the igneous rocks, with a range in the silica constituent, from 65 to 80 per cent.

VARIETIES OF GRANITE.—From a mineralogical standpoint, the prevailing accessory mineral present serves as a basis for classifying or naming the various kinds of granite. Therefore, according to whichever one or ones predominate, we have the following more commonly occurring varieties: Muscovite granite, biotite granite (granitite), muscovite-biotite granite, hornblende granite, hornblende-biotite granite, augite granite; and occasionally, epidote, tourmaline or schorl, and chlorite granite. Aplite is a term used by the Germans to designate a fine-grained granite composed almost entirely of quartz and feldspar with but little or no mica, and occurring mostly in dikes. The name, granitell, has also been applied to rocks of this class. Pegmatite is a coarse-grained vein or dike rock, consisting of an admixture of the essential minerals, quartz, the acid feldspars, orthoclase, oligoclase, albite and microcline—the last two being especially characteristic—with, in some cases, a somewhat large proportion of rare minerals, and the more acid micas, muscovite and lepidolite, and less frequently biotite, and is considered a product of aqueo-igneous action.[1] Greisen is the name applied to a rock consisting chiefly of quartz and mica, with accessory topaz in some cases; and is regarded as a product of fumarolic action. The name unakite has been given a granite rich in epidote with pink feldspars, occurring in the Unaka mountains of Eastern Tennessee and Western North Carolina. Protogine, though not very generally used, is the name given to the variety of granite, in which the mica has been wholly or in part replaced by talc.

The varieties of granite, occurring most frequently in the United States, are very largely biotite, muscovite and biotite-muscovite granites, and hence may be referred to as mica granites. The biotite granites greatly predominate.

[1] Crosby, W. O., and Fuller, M. L., Origin of Pegmatite, Tech. Quart., 1896, Vol. IX, pp. 326–356; American Geologist, Vol. XIX, p. 151.

GENERAL PHYSICAL PROPERTIES.—The average specific gravity of granite is 2.66, which is equivalent to 166½ pounds per cubic foot, or, approximately, two tons per cubic yard. Merrill[1] says, that, according to Prof. Ansted, granites ordinarily contain about 0.8 per cent. of water, and are capable of absorbing some 0.2 per cent. more; a cubic yard of the stone usually contains, therefore, 3.5 gallons of water. The compressive or crushing strength of granite varies somewhat widely; though it is usually included within the limits of 15,000 to 20,000 pounds per square inch.

The granites vary in color, from a common light mottled-gray, through a very dark blue-gray, to deep red or pink, imparted by the abundance and kind of accessory minerals, and the vari-colored feldspars present. A granite, in which muscovite is the characterizing accessory mineral, is prevailingly light-gray in color; while the dark colored varieties invariably owe their deep color to an abundance of black mica (biotite) or hornblende. All gradations between these two shades occur, according to the relative abundance and kind of the ferro-magnesian mineral, or minerals, present as the characterizing accessory, and according to the tint of the feldspars, and, in some cases, the quartz. The various shades of green, pink and red, frequently observed, are largely due to the similarly colored feldspars present.

GEOLOGICAL AGE AND MODE OF OCCURRENCE.—The granites are massive, holo-crystalline, granular rocks. They were firmly held at one time to be the oldest of known rocks. As Sir A. Giekie[2] says, this idea doubtless originated from the fact, "that granite is found rising from beneath gneiss, schist and other crystalline masses, which, in their turn, underlie very old stratified formations." On the contrary, granites are not in all cases, as was once supposed, the oldest of rocks; but they are found associated with and breaking through rocks of all ages, up to late Mesozoic and early Tertiary time. They do, however, occur most frequently associated with the older rocks of the earth's crust, in the form of large eruptive bosses intruded into the overlying rocks, and oftentimes interstratified with the various metamorphic gneisses and schists, forming the central part or core of mountain chains. It follows, therefore, from the origin of granite, which is discussed on pages 28–30, that its occurrence with the older and lower, instead of with the newer and higher rocks of the earth's crust is natural, and what would be expected. As determined by Whitney and Zirkel, and, later, by geologists on the U. S. Geological Survey, the occur-

[1] Merrill, Geo. P., Stones for Building and Decoration; John Wiley & Sons, New York, 1897; 2nd Ed, p. 228.

[2] Geikie, Archibald, Text-Book of Geology, 1893; 3rd Ed, p. 565.

rence of granite in the western United States, ranges in age, from Archæan up through the close of Jurassic time. Most of the granites of the eastern United States have been considered of Archæan age, though recent writers ascribe different periods of intrusion, in the various portions of the Atlantic Border belt. Some of the Vermont granites are considered by Hitchcock as having been erupted, or protruded, during Silurian, or even Devonian, time. Recently, Prof. Emerson[1] has concluded, from a study of the relationship of the granites and tonalites of Old Hampshire county, Massachusetts, to the surrounding schists and other rocks, that they are of late Devonian or Carboniferous age. Granite does not, therefore, belong exclusively to any one geological period; but it has been intruded, at various periods.

THE HISTORY AND USES OF GRANITE.—A brief statement, relating to the historical introduction of the use of granite in the United States, may prove of some interest. As far back as the reign of Zestus, King of Thebes, 1,300 years before the Christian Era, the granite of Syene ("Syénite rose d'Egypte") is stated[2] to have been extensively quarried by the Egyptians, and fashioned into various columns, obelisks, sarcophagi and statues. These are to be found, at present, adorning the various cities of the old world, more especially those of modern Europe. Of more recent date, are the granites of Italy and the adjacent islands (principally Sardinia and Elba), France and the British Isles.

The first authentic record[3] of the use of granite in the United States was in the construction of stone buildings in Boston, Massachusetts, between the years 1630 and 1650. The stone was obtained from the loose, scattered boulders in the vicinity of Boston. The methods employed for splitting and shaping the rock were crude and expensive, and resulted in but few structures being built therefrom. The beginning of the present century, however, inaugurated changes in the method of splitting the stone; namely, that of drilling holes and driving in wedges,[4] which method is in vogue at the present time. The Massachusetts State prison in Charlestown, finished in 1805, and the Bunker Hill monument and Kings chapel of the same place, were the first structures built of granite split according to the above method. The use of granite in the United States properly dates from the building of the above structures in Charlestown. For

[1] Monograph XXIX, U. S. Geol. Survey, 1898.

[2] Edward Hull, Op. Cit.

[3] Wolf, J. E., 10th Census Report, Vol. X, pp. 282-285.

[4] Technically, "plug and feathers."

many years, quarrying was restricted to the loose boulders; and the first account of any ledge quarrying was about the close of the first decade of the present century. Work was limited, for some time, to two varieties; namely, the so-called Chelmsford light-colored granite, from near Lowell, Massachusetts, and the dark-colored Quincy granite, of the same State. As early as the year 1818, this granite is said to have found its way into Georgia; and a church in Savannah was built of it, $25,000 worth of the stone being sold, it is said. It is further stated,[1] that in 1848 there were as many as thirty to forty blocks of granite buildings in the city of Boston.

Up to within the last twenty years, however, the use of granite in this country was in heavy massive forms of architecture, and was then introduced, probably not more on account of its desirability by the people, than because of its ready accessibility, when transportation and labor were, as now, the important controlling factors. Within the last two decades, however, the value of this stone, from an artistic, as well as other points of view, for ornamental and interior decorative work, has been thoroughly tested, as displayed in the interiors of the numerous public buildings throughout the large cities; and by shafts and monuments in our cemeteries. Its wide range in properties, such as, hardness, structure and texture, strength, susceptibility to high and permanent polish, and especially the various and numerous shades and tints of color, requisite qualities, eminently fits this stone for all kinds and grades of ornamental and decorative work. It rightly deserves first rank as a building and ornamental stone, since it more nearly meets the universal needs and requirements, than any other. Precedence is given it, over all other stones for monumental work. For street purposes, in the form of Belgian blocks and curbing, it has been thoroughly tested; and a large number of the streets of our principal cities are paved with this stone. Further uses are made of it, for piers, dams for breakwaters, retaining walls and steps, and in bridge and culvert construction. Wherever stone of great durability is required, granite is used.

The importation of granite from various foreign localities into the United States, mainly as monumental stone, has been greatly reduced, on account of, first, the tariff imposed on such material; and, second, the abundance, variety, superior quality, ready accessibility and workability of the granites within our own confines.

THE ORIGIN OF GRANITE. — As early as 1768, before Werner had commenced his work at Freiberg, Raspe had advocated an

[1] Wolf, J E., Op. Cit.

igneous origin for the basalts at Hesse. Werner subsequently made observations on the basalts of Saxony and Hesse, concluding, that they were not of igneous origin, but were chemical precipitates from water. Thus arose a long and bitter controversy between the two opposing schools of geologists, the Vulcanists, who advocated the formation of certain rocks by igneous, subterranean forces, and the Neptunists, who favored origin by aqueous forces. About this time, Desmorest, after a careful survey and mapping of the rocks of the volcanic district of Auvergne, France, established, in a masterful way, their igneous origin, although unable to convince the Wernerian school.

Guided by the absence of stratification in granite and its analogy, in mineral character, to rocks, which he considered of igneous origin, Sir Charles Lyell says, that Hutton was led to believe, that granite was also of igneous origin, and was the first one to prove it. Not satisfied with theory alone, Hutton set about to find some facts, from field evidence, in support of his theory, having in view mainly the discovery "at the contact of granite and other strata a repetition of the phenomena exhibited so constantly by the trap-rocks."[1] Sir Charles Lyell also states,[2] that Hutton went to the Grampians, to test his theory, by surveying the contact between the granite and the superincumbent stratified rocks; and, when at Glen Tilt, he found in 1785, "the most clear and unequivocal proofs in support of his views". The proof consisted of red granite veins (apophyses) intersecting the mica schist and limestone, given off from the main granite mass; and alteration of the schist and limestone at the line of contact, which is strongly marked by metamorphism from the intruded granite mass.

Afterwards, when the igneous origin of granite was well established, many geologists believed, that some granites were of metamorphic origin, inasmuch as gradations into gneisses, through crystalline schists and unaltered strata, were seemingly traceable, the granite representing the extreme, and the gneiss a less advanced stage of the process. Granite is now regarded as an igneous rock; and where such gradations into gneiss and schist occur, they are looked upon as an alteration, accomplished through the agencies of metamorphism of the original granite. Cases abound, where gneisses can be shown, beyond doubt, to have been derived from granite; these are sometimes called *foliated granite* or *granite-gneisses*. While some gneisses are derived from an original granite mass, others are as certainly the derived products of metamorphosed sediments.

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[1] Principles of Geology, 1883, 11th Ed., Vol. I, p. 74.

[2] Ibid.

Granite, then, is, from its position in the earth's crust, referred to and classified as a plutonic rock; that is to say, a rock, which, under certain peculiar conditions of heat and pressure, has cooled from a molten state, at varying but great depths under masses of overlying rock, into which the molten mass was intruded from the earth's interior. Wherever granite is exposed at the existing surface, it is believed to be due to the removal, by denudation, of the superincumbent masses of rock, under which it originally consolidated. From these conditions, necessarily follows the holocrystalline, granular structure of the granites, whose individual mineral grains are irregularly and intricately interlocked, imparting thereby great strength to the rock.

The evidence, upon which rests the recognition of the igneous origin of granite and other rock-masses among the older crystalline rocks, similar to those of the Piedmont belt of Georgia, depends in part upon their field relations, and in part upon their chemical and microscopical characteristics.

The rhyolites (liparites) have the same chemical composition as the granites; but they differ in texture, and slightly in mineral composition, and are considered the volcanic or effusive equivalents of granite. The two are grouped as the granite (plutonic or intrusive) and rhyolite (volcanic or effusive) groups of rocks. The distinction is based primarily upon the position of the two in the earth's crust; the granites being formed deep below, while the rhyolites were formed at or near the surface of the earth.

GEOLOGICAL AND GEOGRAPHICAL DISTRIBUTION OF GRANITES IN THE UNITED STATES

Granites are among the most common and wide-spread rocks of the United States. They occur principally along the Atlantic Border or Appalachian region; in the western bordering States of the Great Lakes; and in the mountainous regions of the west, beginning with the front range of the Rocky mountains and extending westward to the Pacific coast. Smaller detached areas occur in several of the Interior Basin and Gulf States, especially Missouri, Arkansas and Texas.

Since the granite industry has been, until very recently, almost entirely restricted to the Eastern or Atlantic Border States, the other areas may be dismissed in a few words.

I The granites of the Western United States have been, up to the present, only sparingly quarried. While the rock abounds in both quantity and quality throughout various portions of the West, quarrying is limited almost exclusively to California, Colorado, South Dakota, Montana and Oregon; and it is carried on sparingly in Utah, Idaho, Nevada, Washington and Wyoming. The granites of this section range in color, from light-gray to red; and in texture, from fine to coarse grain; and they generally carry biotite as the principal accessory mineral. In extent, they range from the Eastern Rocky mountains to the Pacific coast, and from Montana and Wyoming to Utah, in a north and south direction. Various periods of intrusion have been assigned them, ranging in age from Archæan up through Jurassic time. The first producing quarry was opened in 1853, in the State of California. The valuation of production[1] from 1890 to 1897 inclusive, by States, is:—

California	$5,199,547
Colorado	956,958
South Dakota[2]	693,524
Montana[3]	93,800
Idaho	19,497
Navada[3]	12,100
Utah	29,030
Washington[3]	5,800
Oregon	74,700
Total	$7,084,956

II In the Middle West and Northern Great Lakes region, quarrying is confined almost exclusively to two States; namely, Minnesota and Wisconsin, both of which yield large quantities of excellent granite of the gray and red, fine- and coarse-grained varieties, carrying hornblende and biotite as the chief accessory minerals. According to Professors Chamberlin and Winchell, and Dr. Buckley, the granites of these two States are pre-Cambrian in age.[4]

The first active quarry was opened in Minnesota in 1868. The output[5] of granite in these two States, for the years 1890 to 1897 inclusive, was $3,241,266, as follows:—

1 Nineteenth Ann. Rept., U. S. Geol. Survey, 1897–98 (1898), Part VI, p. 211.

2 A part of this is the Sioux Falls Quartzite.

3 Total valuation for 1890 in Montana, Washington, Nevada and Arkansas equals $76,000.

4 See the State reports issued by the Geological and Natural History Surveys of Wisconsin and Minnesota.

5 Nineteenth Ann. Rept., U. S. Geol. Surv., 1898, Pt. VI, p. 211.

Minnesota	$1,537,319
Wisconsin	1,704,947
Total	$3,241,266

III In Missouri and Texas, limited areas of red and gray colored granites have been worked. They consist chiefly of the biotitic variety; although, in the former State, the red granites carry but little of the accessory mineral. The Arkansas rock, while it is worked and marketed, to some extent outside of the State; and while it is of fine quality and pleasing color, is not, petrographically speaking, a granite; but it is classed as an elæolite-syenite (fourchite).[1] The output[2] in these States for the years 1890 to 1897 inclusive, was $2,370,897, proportioned as follows:—

Missouri	$2,047,756
Texas	190,041
Arkansas	133,100
Total	$2,370,897

Quartz porphyries, granite porphyries and rhyolite occur in various places over the western and northern areas of the United States above described, which, on account of their occurrences, and their mineral and chemical composition, are grouped as granitoid rocks, and are employed, to some extent, for certain economic structural work.

THE GRANITES OF THE ATLANTIC BORDER, OR APPALACHIAN REGION, OF THE UNITED STATES

Throughout the entire length of the Appalachian, or Atlantic Border, region, from Northern New England to South Central Georgia, similar geologic agencies have operated in producing closely similar results. Contemporaneity of sedimentation and uplift, eruption and metamorphism have obtained throughout this belt, with hardly more than variation in detail. The geologic forces operating and the results produced have been remarkably

[1] Williams, J. Francis, The Igneous Rocks of Arkansas, Ann. Rept., Geol. Surv. of Ark., 1890, Vol. II.

[2] Nineteenth Ann. Rept., U. S. Geol. Surv., 1898, Pt. VI, p. 211.

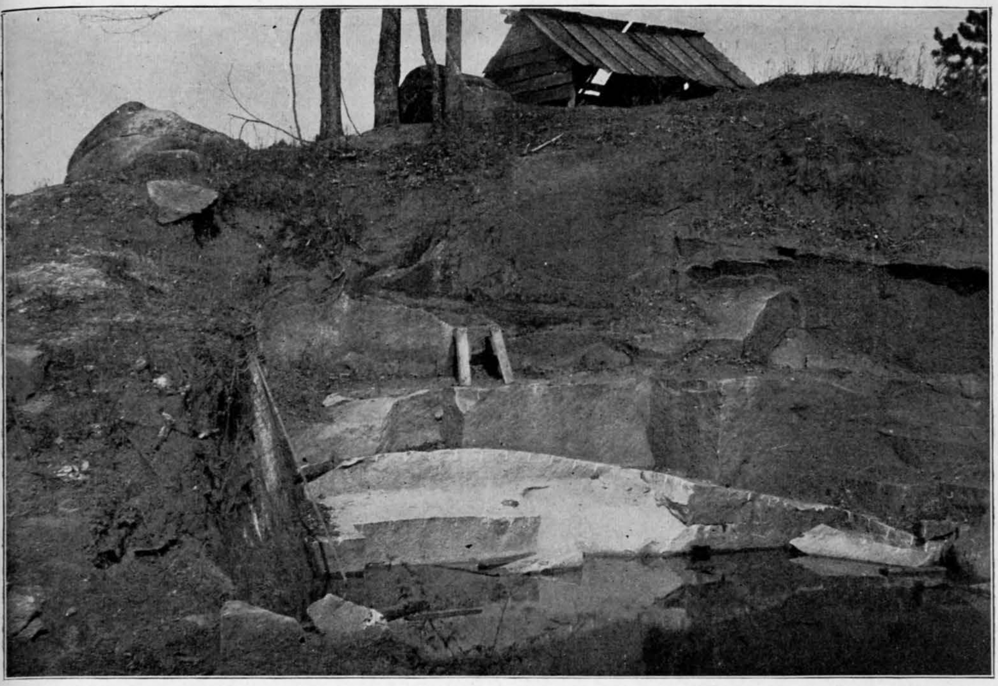


Fig. 2

THE GREENVILLE GRANITE COMPANY'S QUARRY, NEAR GREENVILLE, MERIWETHER COUNTY, GEORGIA, AND THE ERODED SURFACE IN THE ACCOMPANYING RESIDUAL CLAY.

Fig. 1. Shows the Graduation from the Residual Clay to the Fresh Granite.
Fig. 2. A Gullied Slope in the Deep Red Plastic Clay Derived from Biotite Granite.

uniform over so wide a territory. Local causes have been active in producing minor changes over various parts of the belt, differing somewhat in action and result; but they have not succeeded in obliterating or masking the phenomena, resulting from the general regional forces.

After leaving New England, the belt of igneous and metamorphic crystalline rocks, bears very rapidly inland, until after leaving New York, it is, with but few exceptions, inaccessible to navigation, necessarily restricting transportation to rail, in most of the Southern Atlantic States. Nature has further favored the northern section, as far south as Southern Pennsylvania, by removing the entire mantle of residual decay and exposing the hard and fresh rock, by glacial action, which has greatly facilitated quarrying over the entire New England region. Notwithstanding the depth of residual decay covering the fresh rock, throughout the South Atlantic States, the rock outcrops are abundant, and quarry location is by no means difficult.

Granitic rocks occur, to some extent, in each of the Atlantic Border States, comprised within the above defined limits. A general and brief description of the geologic and geographic occurrence and distribution of the granites, and the granite industry in the various Atlantic States, is here given:—[1]

CONNECTICUT.—Both granites and gneisses have been extensively quarried in this State, limited, for the most part, to the following counties: Litchfield, Fairfield, New Haven, Middlesex, New London, Windham, Tolland and Hartford. But few of the Connecticut stones are said to have been marketed outside of the State, the greater bulk having been quarried almost exclusively for local use. The granites are characterized as fine, even grained to porphyritic rocks in texture, and light-gray to red in color; and they carry both muscovite and biotite as the chief accessory minerals, with the latter prevailing. The pink colored orthoclase phenocrysts in the coarsely porphyritic granite of Leetes Island are said to measure two inches and more in length. A coarsely crystalline red granite is said to occur at or near Lyme, in New London county, which rivals in beauty the celebrated Scotch granite at Peterhead; but it is not worked on account of its being too expensive. Very dark-gray hornblende gneisses, carrying in addition some biotite, are worked for strictly local uses at Haddam, Greenwich and Bridgeport. The granite output in this State, for the years 1890 to 1897 inclusive, was valued at $6,229,952.

[1] The main facts have, for most of the States, been necessarily abstracted from the Annual Reports of the U. S. Geol. Survey, and from "Stones for Building and Decoration, 1897." by Geo. P. Merrill. Credit is given in the proper places, wherever State Reports or other publications were used.

DELAWARE.—The production of granitic rocks in Delaware is very limited. The only locality, where quarries have been opened, is near Wilmington. The rock is a dark-gray augite-hornblende gneiss, used for general building purposes in the city of Wilmington. A large increase in production, however, was realized in 1897, when a considerable quantity of the rock was quarried for use as breakwater stone, by the U. S. Government. The output, for the years 1890 to 1897 inclusive, was valued at $1,474,345.

MAINE.—Extensive areas of granite and gneiss occur throughout the State and the adjacent islands. The entire coast-line of Maine is composed of granitic rocks, more or less suited to general construction work, which, owing to the advantageous conditions for the ready handling of the stone at, and the transportation by water, has opened up a multitude of quarries along its coast, thereby rendering it one of the foremost States in the granite production of the United States.

According to Prof. C. H. Hitchcock,[1] the principal granite areas of the State are the Mount Katahdn area; the Washington County area, included between Penobscot bay and Schoodic lake, and extending in a northeast direction into and through New Brunswick, with an estimated length of 290 miles, and width of from 10 to 20 miles; the Mount Desert area; and the Jonesport-Calais (Washington County) -New Brunswick area. Great variety of color and texture is observed among the granite rocks of Maine. They vary from light to dark gray, through pinkish to red in color; and from fine, even grained to coarsely porphyritic, in texture. The phenocrysts of feldspar are, in many cases, more than an inch in length, and generally white, though sometimes pinkish, in color. They consist of both the potash species, orthoclase and microcline. The majority of the quarried stones are biotite granites; although biotite-muscovite, hornblende, hornblende-biotite and chlorite varieties are common. The granites of this State have been widely marketed throughout the United States. So far as is known at present, they are all pre-Cambrian in age. The largest quarries in the United States are located at Vinalhaven, Maine. The output of the State for the years 1890 to 1897 inclusive, was valued at $13,262,647.

MARYLAND.—The occurrence of granitic and gneissic rocks in the State of Maryland is limited to the ancient mass of crystalline and partially crystalline rocks, forming the Piedmont plateau, the southern extension of which crosses Virginia, the Carolinas and Georgia in a southwesterly direction. The quarrying, however, is comprised within a triangular area, bounded on the east by the

[1] Geology of Northern New England.

Coastal Plain sediments, and on the west by the partially crystalline rocks on the western slope of Parrs Ridge,[1] and is confined, for the most part, to the counties of Cecil, Harford, Baltimore, Howard, Montgomery, Frederick and Carroll. The quarries operated are the Port Deposit, Frenchtown, Ellicott City, Woodstock and Guilford, with the lesser ones, at or near Dorsey's Run, Sykesville, Cabin John's bridge, Garrett Park, Brookville and Franklinville; and in the vicinity of the city of Baltimore at Jones' Falls and Gwynn's Falls.

The granites of Maryland are better adapted to general constructional work than for monumental purposes. They contain biotite as their chief accessory mineral, and are light- to dark-gray in color, and medium fine-grained in texture. Some of the areas present porphyritic facies, with the feldspar phenocrysts as large as an inch, and more, in length. The majority of these rocks are granite-gneisses, a result of the action of the agencies or metamorphism, mainly pressure, and recrystallization, on the original areas of massive granites. The output, for the years 1890 to 1897 inclusive, was valued at $2,692,086.

MASSACHUSETTS. — The granite industry in the United States properly dates from the opening of the quarries at Chelmsford and Quincy, Massachusetts, in the early part of the present century (1825), where the stone for the famous Bunker Hill monument at Charlestown was obtained. The principal granitic areas are those at Chelmsford, Quincy, Cape Ann, Rockport, Lynn and Lynnfield. They consist of coarse-grained, dark bluish-gray to greenish colored hornblendic granites. The Quincy rock carries pyroxene in addition to hornblende, and is properly termed a hornblende-pyroxene granite. Considerable black mica of the species lepidomelane, variety annite, occurs distributed through some of the Cape Ann granites.

Coarse-grained biotite granites are said to be worked at Brockton, Milford, North Easton, Framingham, Leominster, Fitchburg, Clinton, Fall River and Freetown. An epidote granite, the only one of this variety marketed in the United States, is quarried at Dedham, Massachusetts. The new Trinity church in Boston is said to be built of this stone.

Numerous fine-grained, light-gray to pinkish colored gneisses are quarried at various places in the State, the most notable localities being in the town of Westford, and at several points in Worcester county. It is stated, that the former is a muscovite gneiss, of fine quality, and that it has been quarried, for the past thirty-

[1] Mathews, E. B., Md. Geol. Surv. Rep, 1898, Vol. II, p. 137.

five years. The largest quarries in the State are those of Cape Ann, in the town of Gloucester. The output in Massachusetts, for the years 1890 to 1897 inclusive, was valued at $16,241,473.

NEW HAMPSHIRE. — According to Prof. Hitchcock,[1] the quarried granites extend, though not continuously, over two-thirds of the central and eastern parts of the State, and belong in age to the White Mountain series. The location of the quarries are at Concord, Fitzwilliam, Milford, Suncook, Farmington, Hooksett, Pelham, Salem, Marlboro, Troy, Sunapee, Allentown, Hanover, Rumsey and Mason. These rocks are for the most part light-gray to white in color, and of fine grain, carrying biotite and muscovite as the chief accessory minerals, associated with, in some localities, hornblende and epidote.

The most important one of the New Hampshire granites is the light colored muscovite-biotite granite, of West Concord, Merrimack county. This is the stone, used for the superstructure of the new Congressional Library building in Washington, D. C.

Gneisses are quarried in various places over the State, for strictly local use, the most notable quarries being those of Peterborough and Lebanon. The output, for the years 1890 to 1897 inclusive, was valued at $4,989,314.

NEW JERSEY. — The so-called Archæan area, which includes all the granitic rocks of the State, is very narrow in width, and crosses New Jersey in a northeast-southwest direction. But few quarries have been opened, yielding mostly a biotite gneiss, which has been used almost exclusively for heavy construction work. The granite proper has been wholly undeveloped, although a hornblende-biotite variety is known to occur in Vernon valley. The output, for the years 1890 to 1897 inclusive, was valued at $2,827,233.

NEW YORK. — Notwithstanding the reported occurrence of gneisses and granites, suitable for general economic purposes, over various portions of the eastern and northeastern sections of the State, the granite industry of New York is comparatively small. Prof. Smock[2] states, that quarries have been opened at various points, in close proximity to the lines of railway along the Hudson river. A coarsely crystalline, gray granite is reported to have been quarried, for many years, at Breakneck and Storm King mountain; but it has been used mostly within the State. Among the true granites, a deep-red, coarsely crystalline hornblende granite, containing some mica, is quarried at several points on Grindstone Island in the St. Lawrence river, for monumental work. The output of granite, the greater part of which was trap-

[1] Geology of Northern New England.

[2] Bull., N. Y. State Museum, 1888, No. 3, p. 11.

rock for road purposes, for the years 1890 to 1897 inclusive, was valued at $1,621,697.

NORTH CAROLINA.—Two belts, or areas,[1] within which the granitic and gneissic rocks are comprised, cross the State, in approximately a northeast and southwest direction. The eastern belt, termed the "Eastern Granites and Gneisses", includes a part, or the whole, of the following counties: Vance, Walker, Franklin, Granville, Warren, Anson, Richmond, Wilson, Halifax and Edgecombe. This area is overlapped by the Coastal Plain formations, on the east, and the Jura-trias and crystalline schists, on the west. The stone, within this belt, has been developed to only a very moderate extent, three quarries furnishing practically all the stone used, which is entirely local, for bridges, pavings, curbings, foundations and, to some extent, buildings. The most extensive granitic masses in the State are limited to the so-called "Piedmont Granite Belt", which is bounded on its east and west sides by crystalline schists. This belt includes those granites occurring in the following counties: Gaston, Mecklenburg, Cabarrus, Iredell, Rowan, Davidson, Davie, Forsyth, Guilford, Alamance, Surrey and Alexander. The most important quarries are those of Dunn's mountain near Salisbury; Mooresville, Iredell county; and near Mt. Airy, in Surrey county. The granites of North Carolina occur in unlimited quantities, and are of excellent grade, displaying great variety of color and texture. They are well suited to all grades of construction and decorative work. They are prevailingly of the biotite variety, although some muscovite and hornblende occur in places, as characterizing accessories. In color, they vary from light- to dark-gray through pinkish to red, and in texture, from fine, and even coarse, granular through porphyritic facies. The output in the State, for the years 1890 to 1897 inclusive, was valued at $702,580.

PENNSYLVANIA.—This State furnishes nothing in the way of granitic rocks to the markets, outside of its own limits. Up to the present time, all the stone quarried is gneiss, with the quarries grouped within close proximity to Philadelphia. These rocks are comprised within the "Southern Gneissic District", as defined by the Pennsylvania Geological Survey. This district extends from the Delaware river, at Trenton, to the Susquehanna, and lies south of the limestone valley of Montgomery. The quarried rock is limited to three counties; namely, Berks, Delaware and Philadelphia. These gneisses vary from light- to dark-gray in color, and contain biotite and hornblende, with, in places, some muscovite, as the characterizing accessory minerals. The rock is used mostly for foundations in Philadelphia.

[1] Lewis, J. V., 1st Biennial Report, N. C. Geol. Surv., 1891–'92, pp. 57–111.

RHODE ISLAND.—The granites of this State are particularly noted and prized as monumental stones. They are fine and even grained in texture; light-gray to pink in color; and consist largely of the biotitic variety, although muscovite and some hornblende occur, in certain localities, as characterizing accessory minerals. For monumental stock, the Westerly and Niantic granites are widely known throughout the United States. Unusual care is exercised in selecting the stone at the Westerly quarries, incurring, at times, it is said, financial loss, in sustaining the standard and high reputation, the stone bears in all the markets, where it has been shipped.

Other areas in the State, where granite is quarried, are Centerdale, Pascoog, Newport, Smithfield, West Greenwich, Narragansett, Coventry Center and Greenville. The yield in production from these localities is small, when compared with Westerly and Niantic; and it is not marketed outside of the State. A greenish hornblende gneiss, of fine texture, is said to be quarried at Diamond Hill, Providence county. The output for Rhode Island, for the years 1890 to 1897 inclusive, was valued at $5,746,768.

SOUTH CAROLINA.—The production in this State is mostly for local consumption. Notwithstanding the quantity and superior quality of the stone found, no considerable amounts have been placed in any of the markets outside of the State. A fine and even textured, gray biotite granite, of excellent quality, is quarried near Winnsboro, Fairfield county. A granite, of a slightly pinkish hue, is also said to occur in the same county. Other counties, in which granite occurs are Charleston, Aiken, Lexington, Richland, Edgefield and Newberry. The South Carolina rocks are prevailingly biotite granites, with some hornblende occurring in the Fairfield County stone. The output, for the years 1890 to 1897 inclusive, was valued at $414,179.

TENNESSEE.—Slight outcrops of granite and gneiss are said to occur in several counties, in the eastern part of the State; but the stone is suitable, in the majority of cases, only for the roughest work. In Cocke county, a very coarse-grained epidotic granite, of a greenish cast, containing large porphyritic crystals of red orthoclase occurs at Bench mountain; but it has never been worked.

VERMONT.—More than two-thirds of the granite output in Vermont is estimated to come from the quarries at or near Barre; and the stone is known in the markets as Barre granite. This stone varies in color from light-, through medium- to dark-gray, the latter being the most valuable, because of stronger contrast between the polished and hammered surfaces. The Barre rock is a biotite-muscovite granite. The quarries are located along a ridge, several miles from the town of Barre, to which the rock is transported by both rail and wagons. The stone occurs in sheets, varying from a few inches to several feet in thickness. Other granites occur in Essex, Orleans, Caledonia, Washington and Windsor counties. These are biotite and biotite-muscovite varieties. A continuous belt of gneiss, beginning at the Massachusetts State-line, extends through the middle portion of the State into Canada, yielding much valuable material for local use. The true granites of Vermont are regarded by Prof. Hitchcock as of Silurian, or possibly Devonian age.

Owing to lack of water transportation, the granite industry of Vermont has not been as extensively developed, as that of the other New England States, where variety and occurrence are as abundant. The output for this State, for the years 1890 to 1897 inclusive, was valued at $5,089,314.

VIRGINIA.—As mapped by Rogers[1], the Archæan area in Virginia comprises a belt, having a general northeast-southwest direction, and is limited on the west, by the Blue Ridge, and on the east, by the Coastal Plain sediments. Quarriable material occurs in various places over the belt. The principal quarries are located near its eastern edge, in the vicinities of Richmond and Petersburg, occurring in the counties of Chesterfield, Dinwiddie and Henrico, on or near the James river. The quarries near Richmond have produced a large supply of stone, which has been marketed in all the States south of New England, being used for general building and monumental work, and for street purposes. One of the most elaborate buildings in this country, the War, State and Navy Building in Washington, D. C., was constructed of the Virginia granite.

A fine-grained, light-gray muscovite-biotite granite, not yet quarried to any extent, occurs near Fredericksburg; it is said to resemble very closely the Hallowell (Maine) and Concord (New Hampshire) granites. A rock, closely resembling the Unakite of East Tennessee and Western North Carolina, is said to exist at Milan's Gap, Madison county. It is described, as a coarse-grained, somewhat porphyritic granite, consisting of quartz, dull red feldspar, and aggregates of dull green epidote.

A blue-gray biotite gneiss is quarried for local use in the vicinity of Lynchburg, in the counties of Amherst and Campbell. Muscovite granite is reported as occurring in Spottsylvania county.

The Virginia granites are all biotite bearing, and generally medium-coarse grained and light-gray in color. They are said to correspond very closely with those of New England. The output, for the years 1890 to 1897 inclusive, was valued at $1,413,174, which, for the last four years of this period, was remarkably small, owing to the pressing financial condition prevailing throughout the State.

[1] Geology of the Virginias, 1884.

CHAPTER II

THE GENERAL PHYSICAL, CHEMICAL AND ECONOMIC PROPERTIES OF BUILDING STONES, AS RELATING MORE ESPECIALLY TO GRANITE

Much of value has been written in recent years, relating to the physical, chemical and economic aspects of building stones in general, resulting necessarily in more or less re-statement. What follows here, therefore, is, from necessity, largely in the nature of a review,[1] with special emphasis laid on the above properties, as more especially applied to the group of granitoid rocks. Since the valuation of a stone, for building and other economic purposes, depends wholly upon certain external and inherent characteristic properties, physical and chemical in nature, by which the stone is enabled to satisfactorily withstand, or resist, the various forces or agencies tending to destroy it, great importance is naturally placed upon a correct understanding and interpretation of these factors. The determination of such value is based primarily on three methods of investigation, which should be used conjointly at all times, inasmuch as they are mutually interdependent. They are (1) observation in the field and quarries of the natural rock outcrops and exposures; (2) examination of the stone in the various kinds of structures, in which it has been used, after many years standing, to test its ability to withstand the various forces, to which it is subjected; and (3) laboratory tests.

DURABILITY

DURABILITY is a most necessary desideratum in the valuation of a stone; since it may be ever so accessible and workable, and yet have no value as a building stone. This quality of a stone may be defined as the rock's capacity to withstand the sum of those forces, chemical and physical, which tend to destroy it.

[1] In addition to the numerous text-books published, a number of the State Surveys have issued, from time to time, reports on Building Stones, several of which include somewhat exhaustive and invaluable discussions of properties of stone in general. Two of these, the writer has constantly kept before him, in the preparation of this part of the report (Chapter I, Pt. 2), namely, Bulletin No. 4, Wisconsin Geol. Surv., 1898, by E. R. Buckley, and Vol II, Pt. IIa, Maryland Geol. Survey, 1898, pp. 47-123, by Geo. P. Merrill.

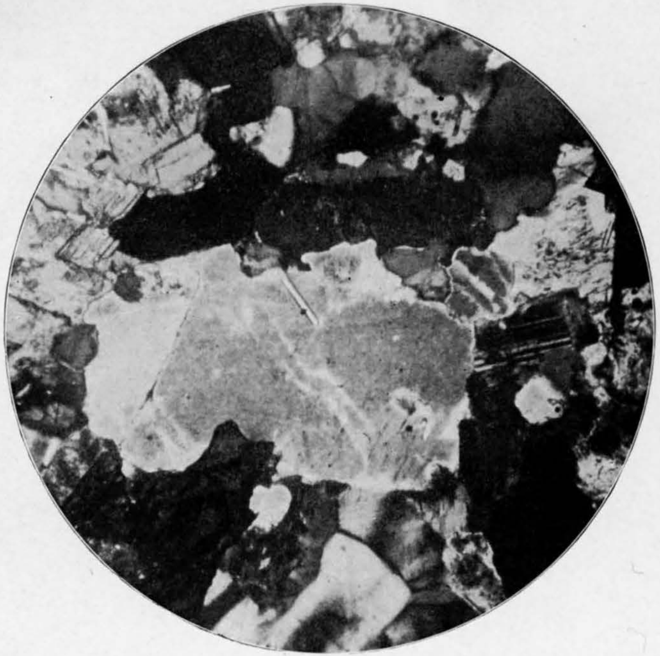


FIG. 1. PHOTO-MICROGRAPH OF DARK BLUE-GRAY GRANITE, FROM THE TIGNER QUARRY, NEAR ODESSADALE, MERIWETHER COUNTY, GEORGIA.
Crossed Nicols x 74.

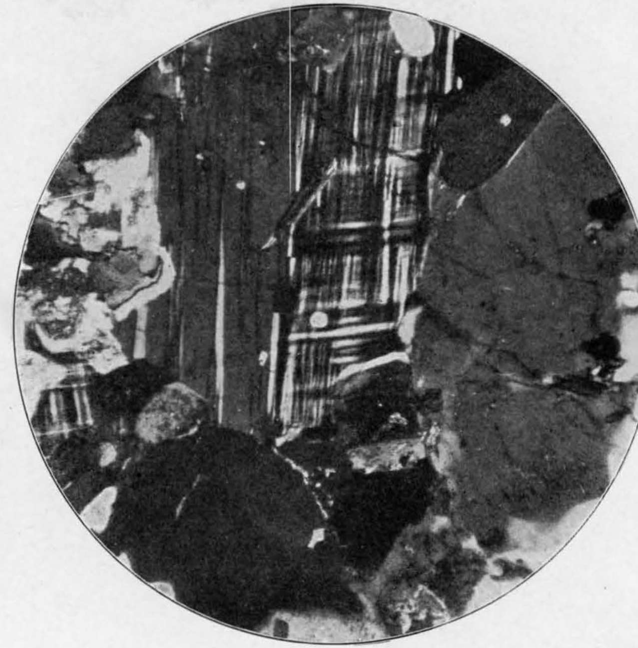


FIG. 2. PHOTO-MICROGRAPH OF THE MEDIUM BLUE-GRAY GRANITE, FROM THE GREENVILLE GRANITE COMPANY'S QUARRY, GREENVILLE, MERIWETHER COUNTY, GEORGIA.
Crossed Nicols x 74.

This is made clear, when it is known that certain inherent characteristics or qualities, which render a stone peculiarly suited for one use, may render it entirely unsuited for another. To illustrate: Certain inherent qualities required of a stone, adapted to an extreme climate, such as alternate freezing and thawing, are not essential, when used in a climate that is uniform. Likewise, a stone required to be used in a locality, where free acid gases predominate, would necessitate certain qualities, not requisite in a stone, for use in a locality, free from such impurities.

All things being equal, therefore, a stone's capacity to withstand such destructive forces will, as stated by Buckley,[1] depend largely upon the following inherent factors: (1) Mineral composition; (2) Texture; (3) Hardness; (4) Strength; and (5) Structure.

MINERAL COMPOSITION.[2] — A granite, as elsewhere defined, is a holo-crystalline rock composed of the essential minerals, quartz and an alkali feldspar, either orthoclase or microcline, or both, with generally a third important or characterizing accessory mineral belonging to the ferro magnesian group of minerals, mica, pyroxene or amphibole. In the case of the Atlantic Border granites, biotite is the prevailing characterizing ferro-magnesian accessory, although hornblende frequently occurs in many of the New England rocks. Other accessory minerals are almost always present in association with the above, but not in sufficient quantity to impart any distinctive character to the rock. At times, however, and from the standpoint of weathering, plagioclase occurs in quantity, sufficiently large to merit some attention.

Of the two essential minerals in granite, quartz and feldspar, the former is the more refractory toward purely chemical agencies. It suffers principally through the effects of mechanical agents, which cause disintegration chiefly through unequal expansion and contraction, alternate freezing and thawing, and pressure. The removal of silica, during the process of decomposition of a silicate rock, is derived very largely from the silicate minerals, and not from the quartz.[3]

Investigation, by various workers, indicates, that the potash feldspar species, orthoclase and microcline, are, as a rule, very much more refractory under climatic conditions, than the more basic soda-lime or plagioclase feldspars. This conclusion has been amply verified, in recent years, by chemical analyses of fresh

[1] Building and Ornamental Stones of Wisconsin, Bull. No. 4, Wis. Geol. Surv, 1898, p. 35.

[2] Only the igneous rocks and metamorphic gneisses, regardless of origin, will be treated.

[3] Merrill, Geo. P., Rocks, Rock-Weathering and Soils, 1897, p. 234.

rocks, and their corresponding residual decayed products, which, by calculation, invariably show, for the igneous rocks, a greater loss in the soda, than in the potash content, both being known to have been derived exclusively from the component feldspar species present in the rock. Until the rock has reached an advanced stage in weathering, the potash feldspars may lose but little by decomposition; but they will become weakened, and will be made to crumble by a mechanical splitting up, along the cleavage lines (*disintegration*). The final result in the weathering of the potash feldspars is, in the presence of alkaline and carbonated waters, the removal of the potash by solution, and the formation of kaolin. The incipient stage of kaolinization of any feldspar individual may be recognized by the dullness and opacity of the surface, consequent upon such change. A step further usually results in the formation of muscovite, some calcite, and kaolin. The alteration products are, however, largely controlled by the species of feldspar, present, and the agencies, that are active in producing the change. Feldspathic alteration progresses, at times, principally along the cleavage planes, when the size of the individual becomes an important factor in its weathering.

The characterizing accessory mineral stands next in importance to the two essential minerals in the granites, which in the case of the Georgia granites is biotite, including quite frequently the colorless mica, muscovite, in intimate association with the biotite, and in sufficient quantity to classify the rock as a biotite-muscovite granite. With but few exceptions, biotite is the prevailing accessory mineral, present, in the Atlantic Border granites. This, however, is, in certain localities, replaced in part or in whole by hornblende or muscovite, and, rarely, by augite. Other things being equal, the biotite, hornblende and augite generally prove less durable than the feldspar, in potash-feldspar granitic rocks, owing to the assumption of water (hydration) accompanied by a higher oxidation of the iron. The colorless mica, muscovite, a silicate of potash and alumina, is, when present as a primary constituent, very much more stable, under climatic conditions, than the black species, biotite.

Owing to the eminent cleavage, imparting a highly fissile structure to the mineral, all micas admit of a ready percolation of water along the cleavage planes, which in the case of the black mica, biotite (a silicate of iron, magnesia and alumina), results in a more ready disintegration, by the presence of water, and decomposition from the peroxidation of the iron, a change from the ferrous to the ferric state. Among the early changes to be noted in the alteration of biotite, are a gradual loss of elasticity in the foliæ, accompanied by loss of transparency and leaching, resulting in a bronze colored luster on the surface. In the more advanced stage of alteration, the mica foliæ gradually crumble away, upon further removal of the bases in solution. Its decomposition, however, is brought about very slowly, and its occurrence in the form of small, thin foliæ, instead of large stout crystals in the Georgia granites, renders the biotite more refractory, and accordingly, less susceptible to change, than otherwise.

The varieties of pyroxene and amphibole, rich in iron, when occurring as accessories, are less desirable, on account of the comparative readiness, with which they decompose, through means of oxidation of the iron from the ferrous to the ferric state. The iron-free varieties of pyroxene and amphibole are more stable under ordinary atmospheric conditions, and are, therefore, more durable and desirable as mineral constituents.

The commonly occurring sulphides of iron (pyrite and marcasite) are objectionable accessories in a rock, when present in appreciable amounts, on account of the readiness, with which they oxidize, causing unsightly discoloration.

TEXTURE.—Texture becomes a very important factor in the durability of a rock, since it conditions, in part, the pore space, upon which a number of other requisite properties rest. Increase the pore space, and the rock's capacity for absorbing water is increased, the deleterious effect of which is apparent in extreme temperatures. In addition to this, the rock's strength to withstand strains, to which all stones are subject, in large massive structures, is accordingly diminished.

The manner of contact, uniformity in size, and closeness of the individual grains, are the controlling factors, conditioning texture. The pore space varies with the kind of rock, the manner, in which the individual grains are brought into juxtaposition, and the size of the mineral particles in the same rock type. Furthermore, pore space and structure are interdependent. The pores in a rock may vary quite appreciably in size, being in many cases too small, to be detected by the microscope.

Under certain conditions, a fine-grained rock may become as porous as a coarse-grained one; the pores, in the case of the fine-grained rock, not being so large, but more numerous. Recent experiments by Buckley,[1] upon fine-and coarse-grained rocks of Wisconsin, would seem to disprove the idea of some, that the size of grain is indicative of the degree of porosity. Other things being equal, size and uniformity of grain, will, in a large measure, condition the manner of weathering.

[1] Building and Ornamental Stones of Wisconsin, Bul. No. 4, Wis. Geol. Surv., 1898.

In granites, as in other igneous, granular rocks, the individual particles or grains closely and intricately interknit or interlock with each other. The igneous rocks, therefore, as a group, are characterized by an interlocking structure in the mineral particles, which imparts greater strength and reduces the porosity of the stone belonging to this class, by enabling it to resist disintegration longer, thereby increasing the durability. For this reason, the granites have a low percentage of pore space, and, correspondingly, a high compressive or crushing strength.

HARDNESS. — By the hardness of a building stone is meant its resistance to wear. It is dependent, perhaps, more upon the state of aggregation of the component minerals, and the firmness, with which they adhere to one another, than upon the actual hardness of the individual minerals. This is well illustrated in the case of sandstones, which are composed of hard and indestructible quartz grains, that, in some instances, are so put or cemented together, that the stone will crumble, under the pressure of the fingers. In other cases, the quartz grains may be so firmly cemented by silica, as to produce one of the hardest of rocks.

At times, and under certain conditions, however, rock hardness is dependent upon other factors. For, of two rocks having the same uniform-sized grains and a similar state of aggregation, their hardness can only be compared, by that of the component minerals. In still other cases, mineralogical composition becomes a controlling factor, and is well illustrated when the hardness of two granites is compared, in which not only the mineral composition enters, but a knowledge of the relative abundance of the constituent minerals in each case is necessary, as well.

Such tests, however, are necessary, only when the material used is subject to constant friction or abrasion, such as in steps and walks, subject to the friction of the feet; and in dams and breakwaters, subject to the friction of the water; also, in certain other instances, when the material is subject to wind blasts of sand.

In the paving of streets with Belgian blocks, where the stone is subject to such constant and heavy wear, this test becomes an important one.

To sum up the controlling factors of hardness, they are found to be — (1) Aggregation of the constituent grains — the firmness or compactness, with which they adhere, thereby diminishing proportionately the pore space; (2) Actual hardness of the individual grains or mineral particles; (3) The size and relative abundance of the component minerals; and (4) The mineral composition.

[1] See page 43.

The state of aggregation of the individual mineral particles in building stone is a most important factor, since it not only conditions, in part, the hardness, but the stone's working qualities, as well.

STRENGTH. — The adaptability and suitability of a stone, for the various kinds of constructional work, have been based, more, in the past, upon the compressive strength of a stone, than upon any other single property. This may be attributed mainly to the fact, that, until recent years, few other tests were made. The value of the test unfortunately has in this way, been greatly overestimated. So thoroughly in accord are the writer's views with those of Prof. George P. Merrill, that he quotes in full from Prof. Merrill's report.[1] "Much has, in times past, been written on the subject of the crushing strength of building stones, and hundreds of tests have been made, * * *. A few words only on the subject are here necessary. It is doubtful if in any but the most extreme cases it is necessary to continue this line of investigation. The results thus far obtained are sufficient for us to formulate general rules, and the average results obtained are so vastly in excess of all ordinary requirements, that they may safely be ignored. A stone so weak as to be likely to crush in the walls of a building, or even in a window stool, cap or pillar, bears so visible marks of its unfitness as to deceive no one with more than an extremely rudimentary knowledge on the subject. It is rare to find a stone that will not show, under the methods of testing now in vogue, a crushing strength of at least 6,000 lbs. to the square inch, while many stones, particularly those of the granite group, will range as high as 20,000 to 30,000 lbs. to the square inch. Since the first named amount is ten-fold more than is likely to be required of it in any but the most extreme cases, the absurdity of making further tests is manifest." Prof. Merrill further says, in this connection: — "In fact, it is the weathering quality of a stone more than its ultimate strength, that should concern us, * * * *".

STRUCTURE. — This is an important factor, in the consideration of any rock, used in the various grades of economic work; since upon it depends, in a large measure, the life and durability of the rock. All parting planes, such as jointing, sedimentary or bedding lines, and schistosity; and all planes of lamination of whatever nature, as well as fractures, are considered planes of weakness in a rock. These render the stone more susceptible to the active agents of weathering, and less suited for certain classes of work, than a massive rock like granite, in which these natural

[1] Merrill, Geo. P., Md. Geol. Surv. Rept., 1898, Vol. II, Pt. IIa, p. 65.

parting planes are absent. Such lines are usually of macroscopic dimensions, and accordingly, visible to the unaided eye, and are commonly referred to as macroscopic structure. There are oftentimes present, however, in all types and varieties of rock, many incipient cracks, such as lines of fracture dividing individual mineral grains—crushed zones, surrounding and filling the interspaces of the component minerals, that cannot be detected by the naked eye. These are due to mechanical stress, and are especially characteristic of the metamorphic rock, gneiss. Such weaknesses are apparent only through the aid of a microscope, and are grouped under the head of microscopic structure.

Again, some rocks are exceedingly fine-grained, in some cases, glassy, and can be passed upon, as to their qualifications for building or ornamental stones, only through microscopic study. Whether a rock is coarse- or fine-grained, a microscopic study is of the utmost importance; since some of the most important factors, such as mineral composition, structure, state of aggregation and impurities of whatever nature, can be definitely determined, in the consideration of stone for economic purposes. Great care should be exercised in the use of laminated stone in structures since it is shown elsewhere in this report, that only the strongest stone should be laid on edge, in large massive buildings. Not only is the structure of a stone of vital importance to the architect and builder, in placing the stone; but it is of untold value to the quarrymen, as well. This is especially true, with rocks of sedimentary origin, where structure and composition are subject to greater variation, than those of igneous origin.

COLOR.—The color of a rock should form one of the essential considerations in the selection of stone. Especially should this apply in large cities, where, in the erection of residences, the color remains unbroken, in frequent continuous rows of buildings constructed out of the same colored stone. In such cases, a judicious scattering of light and dark colored structures, would prove more pleasing from an artistic standpoint, and also add to the beauty of both house and street. In case of the massive structures, common to the business centers of our largest cities, consideration should be had, mainly, in the selection of a stone upon its strength and durability. Also, in certain parts of a structure, especially the steps, the power to withstand abrasion, and not color, should be the controlling element. For interior decorative work and monuments, color should again prove the controlling factor.

The color of igneous rocks (crystalline) in general is ascribed mainly to three causes: (1) Mineral composition—the presence or absence of colored minerals; (2) The distribution and size of the individual minerals; and (3) the physical condition of the feldspar individuals. Accordingly, granites may be grouped as red and gray, dependent upon the color of the feldspar, whether red or white, and sometimes the color of the quartz. The gray granites, according to a preponderance of the ferro-magnesian accessory, and, to some degree, the size of the component minerals, are further classified as light and dark colored granites. The lightest colored granite would, therefore, necessitate a preponderance of white feldspar, with an admixture of the ferro-magnesian constituent, muscovite. An excellent illustration is found in the famous Stone Mountain granite of Georgia. The darker colored granites, likewise, contain proportionately more of the dark colored accessory, biotite, pyroxene or hornblende, and less of the feldspar constituent.

It is observed, that the hammered surfaces of rocks are lighter in color than corresponding polished surfaces. Prof. Merrill's explanation for this[1] is, that the individual mineral grains on the immediate surface of the stone, are so broken up by the impact of the hammer, that the light is reflected instead of absorbed by them, resulting in whiteness. Conversely, a polished surface is rendered darker, owing to the elimination of these and other irregularities of the surface, by careful grinding, resulting in a smooth and even surface, which absorbs, instead of reflects, the light falling upon the surface. This becomes an important factor in the selection of material for monumental purposes, where contrast in polished and hammered surfaces is necessary.

GEOLOGICAL AGE.—Only in a very general way, is the geological age of stone of much economic value. Metamorphism has been active in producing changes in rocks of both igneous and sedimentary origin, belonging to the various geological horizons, with the effect, that the changes have been very much more widespread and complete among the older, than among the younger rocks. While probably in the majority of cases such changes have been productive of rocks, better suited for the various uses they are made to serve; yet it can also be stated, that metamorphism has, in many instances, developed structural weaknesses, and made prominent other blemishes, which render a rock but little suited for any grade of work.

At present, nearly all the stone quarried, to any great extent, in the United States, belongs to the older geological horizons, scarcely any being of later date than Triassic. So far as age relationship has been established, in the case of the granites quarried in

[1] Maryland Geol. Surv. Rept., 1898, Vol. II, Pt. IIa, pp. 63-64.

the United States, up to the present, they belong, in most cases, among the oldest rocks, and are mostly Archæan and Paleozoic in age.

CONSIDERATION OF THE CRITERIA FOR DETERMINING THE VALUE OF STONE FOR GENERAL ECONOMIC WORK

Certain tests are requisite, in all cases, for establishing the correct value of stone required for use in general economic work. As previously stated on page 40, these tests may be summed up, under three general headings, and regarded in the nature of criteria essential to proper valuation, as follows:—[1]

1 Field-study of the natural rock outcrops and exposures, and in the quarries.

2 Careful examination of the stone placed in the various structures, such as buildings, monuments etc.

3 Laboratory tests.

To the trained geologist, the first would prove, in every case perhaps, the most satisfactory. Such observations, however, when conducted singly, are, at best, wholly incomplete; but when careful field-study is combined with the requisite laboratory tests, certain definite conclusions may be reached, regarding the stone's ability to withstand the manifold agencies, to which it is subjected, when exposed in structures. Therefore, no single one of the above criteria should be considered in itself sufficient; but the three should be used conjointly.

FIELD-STUDY

Obviously, the most important factors, upon which the economic quarrying of stone is based, can be obtained by this method only. Oftentimes, stone varies considerably in different parts of the same quarry. The color may not be decided and uniform, throughout the various parts of the same quarry. Certain impurities, which tend to discolor the rock on exposure, such as the sulphides of iron (pyrite and marcasite) may be present in some portions, to the extent of injury, while absent in others. Segregations, blotches etc. may also be numerous over parts of the quarry. Incipient jointing and fracturing may be present in some layers, and

[1] Buckley, E. R., Bulletin No. 4. Wisconsin Geol. and Nat. Hist. Surv., 1898, p. 46.

FIG. 1. PHOTO-MICROGRAPH OF HORNBLENDE-GNEISS (AMPHIBOLITE), FROM THE T. B. TIGNER QUARRY, ON THE MACON & BIRMINGHAM R. R., MERIWETHER COUNTY, GEORGIA, X 74.

FIG. 2. PHOTO-MICROGRAPH OF PORPHYRITIC GRANITE, FROM THE McCOLLUM PLACE, NEAR COWETA STATION, COWETA COUNTY, GEORGIA.
Crossed Nicols x 74.

absent in others; or the jointing, veins and dikes may occur crowded together, rendering the stone unsuited for any kind of work. Lamination, bedding and schistosity planes may occur. Any of these when present are essential, and can be determined only by field observation. Field-study alone can determine, whether the natural exposures are adapted to the opening of quarries, and the grade of work, for which the stone can be used. A knowledge of the extent of the stone, that is, whether in sufficient quantity to justify working, is a factor of vital importance, and must rest solely with this method. Other subsequent elements, of prime consideration, dependent upon field observation, are accessibility and workability of the stone.

Permanence of color and durability of stone may be satisfactorily determined in this way; since the stone in its fresh condition can be contrasted with the weathered outcrops, which, in our Southern States, have been exposed to varying climatic vicissitudes, for an indefinite period of time, resulting usually in a covering of residual decay, of considerable, though varying, thickness. From such an examination and study, a general idea may be gained, as to the rapidity, with which the rock resists weathering, and also the manner, in which such degeneration is brought about; for, frequently, incipient weaknesses, not observable in the fresh rock, are oftentimes clearly visible in the weathered portion of the rock. In this way a careful study of the weathered product is essential, in bringing out any inherent qualities tending to lessen the durability of fresh stone, when placed in structures.

Examination of Stone in Structures of Long Standing

The value of making an examination of the stone, used in buildings and other general economic work, has long been recognized; and, as Buckley states, possibly on account of the readiness and ease, with which such observation can be prosecuted, its value has in many instances been overestimated.

It not infrequently happens, that defective stone is placed in buildings, where the maximum standard of perfection is required. This can be traced directly, as resulting from the use of improper methods in quarrying; from rough and careless handling; and from the dressing of the stone. It cannot, in all cases, be ascribed to an original inherent defect in the stone, as some are inclined to do.

The elements of time, location and size of building are factors, in conditioning the life of the stone used; and they must be considered, in its selection. Contrast the conditions, which surround a building in a large city, with those, to which a building, constructed out of the same stone, in a rural district, are subjected; and it becomes at once apparent, that they are affected unequally, with respect to degree and kind of agent or agencies operating.

At present, granite has come into general use in the cities, for monuments and shafts. The recency, therefore, in the use of granite for monumental work, militates against any data for estimating the stone's durability. In some instances, however, where the first granite shafts were erected in the United States from imported granites, and necessarily of some years' standing, the climatic agencies are beginning to manifest themselves to some degree, mostly in the nature of pitted surfaces and a roughening of the polished faces. The polished face of granite readily exposes to view the various textural irregularities, and, at times, other inherent weaknesses, present in the rock.

An examination of the materials, used in the past, in rough work, such as for street purposes etc., will reveal much, concerning the suitability and desirability of various kinds of stone, used for this grade of work. Other things being equal, the usual requirements to be met, in the selection of a stone for this class of work, are its ability to withstand weight inducing strains of whatever nature; abrasion; alternate freezing and thawing; frost action; and alternate expansion and contraction.

Laboratory Tests

The physical and chemical characteristics of the stone from each quarry should be carefully determined, by a complete series of laboratory tests. This is more often a subject of neglect, than otherwise, among architects, builders and quarrymen. Such tests should be demanded, in every case, prior to the use of any stone, in order that serious results may be avoided after placing the rock in a building. Again, it has been, and is largely the custom to-day, to have only one test made, and that, the crushing or compressive strength test, by which the durability of the stone is measured. This is certainly grossly erroneous; since frequently it happens, that the stone showing the highest crushing strength is less durable, than one having a lower strength, and the other requisite inherent qualifications for durability.

In order that a stone may be judged as suitable for any grade of constructional economic work, it is important, that it be critically examined in the laboratory, as to the presence or absence of any inherent weaknesses, and its power of resistance to the multifarious physical and chemical agencies, to which it necessarily becomes subjected, in all classes of structural work. The important tests involved, therefore, in a wise and judicious selection of a stone, are grouped and treated under the three following general heads: (a) chemical; (b) microscopic; and (c) physical.

CHEMICAL TESTS.—An accurate determination of the elementary composition of a rock is possible, only by means of a chemical analysis. The chemical nature of a rock naturally varies with its mineral composition, and the varying proportions of the component minerals present. In a very rough way only, can a knowledge of the mineral composition of a rock serve as a guide, in approximating the true composition of even the essential elements. This necessarily follows, since, even in the most representative rock types, there is frequently considerable range in the essential elements, such as silica, alumina, lime, magnesia and the alkalies in granites. At present, this variation is believed to be greater, than at first recognized, some years ago; since it is now generally held, by all "philosophical petrographers," that gradations occur between all kinds of the igneous rocks, and hence, there is probably less ground for sharp divisions into well represented rock types, than formerly. For example, a granite may grade into a syenite in one locality, and into a diorite, in another.

The relative and exact amount of any deleterious substance can be ascertained only upon chemical analysis. The presence or absence of such, may be determined as readily by microscopic, as by chemical methods. The two work conjointly, the one serving to confirm the other.

Chemical analysis is always necessary in rock classification; since it is one of the controlling factors, in the classificatory scheme, in vogue among petrographers, at present. The principle is based primarily upon the amount of silica present, the rock taking its place accordingly in the scheme, as either acidic, basic, or intermediate, with reference to the percentage of this ingredient. In the chemical analysis, the determination of the bases, however, is just as essential, to meet the ultimate needs of classification, as the silica.

It is plain, therefore, that chemical analysis is not only valuable, but an essential adjunct, in the consideration and determination of the qualities of building stone. For a detailed discussion of the chemistry of the Georgia granites and gneisses, with the table of analyses, see Chapter IV of this report.

MICROSCOPIC TESTS.—The microscopic study of a rock is probably capable of revealing more, concerning the real value of a stone, from the standpoint of durability, than any other single laboratory test; since its essential physical and approximate chemical elements are thereby determinable. Obviously, therefore, this places the microscopical examination of thin sections of rocks as one of much practical value, and accordingly, of great importance.

By means of the microscope and thin sections, one can readily determine the mineral composition, and the relative abundance, as well as the state of aggregation of the mineral particles, which are important factors in estimating the durability of stone. Chemical analysis, as elsewhere stated, also affords a means for determining the mineral composition of a rock. Microscopic examination will further indicate the manner, in which the individual minerals interlock in the case of igneous rocks; and the kind and relative abundance of the cement, and the closeness, with which the grains are cemented, in the case of sedimentary rocks. It shows, in addition, the structure of the rock, which is a most important factor; and the presence or absence, and the nature of impurities; also strains, cracks, gas bubbles, and other similar weaknesses, as well as the character of each. In all cases, microscopic study is made one of the essentials, in determining the origin and classification of rocks; and oftentimes it becomes the prime factor in such determinations.

Special emphasis will be given the microscopic study and examination of the Georgia granites and gneisses, in the following pages.[1]

PHYSICAL TESTS. — While, in the past, stone has been subjected to numerous artificial tests, of a physical character, for the purpose of determining its durability and desirability for use, it can hardly be denied, that this phase of the subject is fraught with many difficulties. The difficulties, attending such tests, are due mainly to the impossibility of placing the stone under exactly similar conditions, when in use, and of actually representing artificially the forces, to which it is subjected under normal atmospheric conditions. It becomes necessary, therefore, in any one or more tests applied in the laboratory, to exaggerate the normal conditions, so far as they may be known. Furthermore, the natural forces in actual operation, producing change, are subject to wide variation; and the satisfactory application of any set of tests must determine not only the stone's ability to effectively withstand the action of such external forces to-day, but its ability to withstand them, after a long number of years of exposure.

The principal forces, to which stone, used in structures, is necessarily exposed and subjected, are (a) chemical action of the atmosphere; (b) physical action of temperature changes; and (c) the crushing and shearing forces, necessitated from the stone's position in the structure. It will be obvious, that some of these

[1] For a detailed description of the petrography of the granites and gneisses of the State, see Chapter IV of this report.

tests will prove more efficacious, than others; and they should accordingly be more strongly emphasized. The principal tests, at present in vogue, for determining the durability of building stone, may be mentioned, as follows:—

1 Strength Tests. Rarely, the transverse strength and the modulus of elasticity are determined. The test as generally made consists only of the compressive or crushing strength.

2 Permanence of Color.

3 Specific Gravity and Weight of Stone per Cubic Foot.

4 Porosity and Ratio of Absorption.

5 Extreme Heat.

6 Alternate Freezing and Thawing.

7 Alternate Expansion and Contraction.

8 Corrosion—the Action of Various Gases, such as CO_2, SO_3, Cl etc.

Test to Ascertain the Compressive or Crushing Strength

Up to the present time, architects and builders have employed this test more universally, for determining the value of a stone for constructional work, than any other single one. The long period of time, during which, and the great number of varieties of building stone, to which, the test has been applied, enables a correct value to be assigned. It is now generally agreed, that a stone possessing a compressive strength of 600 pounds per square inch, is sufficiently strong for all ordinary building purposes; and any excessive strength is practically of no importance, further than denoting density and, therefore, greater resistance to atmospheric agencies. Since, in all cases, the granites have indicated the greatest compressive strength over all other kinds of building stone, ranging from four to ten times the maximum strength required, it would seem that further tests of this nature on granites would prove of little value, other than to satisfy a long established custom. The numerous tests, already made on the different kinds of stone, have also brought out the fact, that a stone is weaker, when saturated with moisture, than when dry, and has a greater capacity, when laid on bed, than on edge. For the above reasons, this test has generally been omitted, for the Georgia granites. Tests, however, of the most reliable character, have been made on three varieties of the Georgia material; and they are given as follows:—

COMPRESSIVE STRENGTH TESTS [1]

LOCALITY	Test Number	How Tested	Size	Pressure per Square Inch in Pounds
Diamond Blue Granite Company's Quarry, Oglethorpe County, Georgia	7,304	On Bed	3.07 x 3.06 x 3.04	26,340
	7,307	On Grain	3.16 x 2.99 x 3.10	23,860

The following tests on specimens of Stone Mountain granite and Lithonia granite-gneiss were made in 1887, at the Washington Navy Yard : — [2]

LOCALITY	Dimensions	Crushed at Pounds	Remarks
Lithonia	2.00″ x 2.00″ x 2.02″	76,000	
"	2.00″ x 2.01″ x 2.00″	83,400	
" (No. 3) . . .	2.06″ x 2.06″ x 2.09″	52,650	
"	2.01″ x 2.01″ x 2.01″	. . .	Did not crush at 85,000 lbs. pressure.
"	2.00″ x 1.98″ x 1.98″	. . .	Did not crush at 85,000 lbs. pressure.
Stone Mountain . .	2.05″ x 2.00″ x 2.01″	. . .	Did not crush at 85,000 lbs. pressure.
" " . .	1.99″ x 1.99″ x 2.00″	50,325	
" " . .	1.99″ x 1.99″ x 2.00″	48,760	
" " . .	2.02″ x 2.02″ x 2.03″	65,610	

For results of other tests made on specimens of this stone, see under crushing strength tests in Chapter VI.

It will be observed from the above figures, that the compressive strength of these Georgia granites is many times in excess of the maximum required strength of stone, for building or other constructional purposes.[3]

Generally, only the compressive strength test is made on stone used in constructional work; although the transverse-strength and the modulus, or coefficient-of-elasticity, tests have occasionally been made and used.

Other durability tests, which serve to indicate the resistance of the stone to certain physical (mechanical) and chemical forces, generally include absorptiveness, specific gravity, freezing, microscopic examination and chemical analysis; and, less frequently, color, abrasion, heat and porosity.

TEST TO ASCERTAIN PERMANENCE OF COLOR

The change in the color of a rock, used in constructional work, usually results from a change in the form of combination of the

[1] Made at the Watertown Arsenal in 1894.

[2] Granite Pavements, compiled by Venable Bros., Atlanta, Ga., 1893, p. 20.

[3] For an exhaustive series of tests upon American stone, and a general description thereof, the reader is referred to the work of General Q. A. Gillmore, of the U. S. Corps of Engineers, published in the Annual Report of the Chief of Engineers, for 1875.

iron. The most common source for such discoloration is the ready oxidation of the sulphides of iron (pyrite or marcasite) and the protoxide carbonate. Laboratory tests consist, therefore, in detecting the presence of sulphur and the rapidity of oxidation.

Tests, to ascertain the effect and rapidity of oxidation on stone, by means of an artificial atmosphere, have been successfully conducted by Dodge [1] on the Minnesota stone, and, afterwards, by Jackson [2], on some of the California building stone.

Since the Georgia granite is practically free from all substances, likely to produce a permanent change in color, or prove a source of ready discoloration, the color test has been omitted. Pyrite occurs sparingly in the greater portion of the granites and gneisses of Georgia, but not in sufficient quantities, or even distributed in anything like uniformity throughout the rock, to bring the stone into disrepute, on account of unsightly discoloration, resulting from such change, under prolonged atmospheric action.

The test, as performed by Prof. Dodge [3] upon the Minnesota rock, was upon rectangular specimens, varying in size, from one inch to one and a half inches in diameter. The specimens were dried in a bath at 212°F., until all moisture was expelled; after which, they were removed from the bath, cooled and weighed. They were then exposed, in a specially devised apparatus, to the fumes of concentrated nitric and hydrochloric acids, in the presence of black oxide of manganese, giving rise to the evolution of chlorine gas. The fumes thus liberated exercised strong oxidizing and corrosive effects on the samples. After having been exposed for a certain length of time, the specimens were removed and washed, and such changes in color and staining as were produced, were noted.

Specific Gravity

The Specific Gravity of a rock may be defined as the ratio of its density to that of distilled water, at 4° C. (39.2° F.), that is, a comparison of the weight of the rock with that of an equal bulk of distilled water, at the above temperature. Another way of expressing it is: The gravity is the expression for the weight per unit of volume for a stone.

Since the weight per cubic foot, the strength and the absorptiveness (porosity) of the stone are dependent upon density, this property becomes a very important one, practically. Mineral com-

[1] Rept., Geol. & Nat. Hist. Surv., Minnesota, 1872–82 (1884), Vol. I, p. 185.

[2] Seventh Ann. Rept., State Mineralogist, California, 1887, p. 205. [3] Op. cit., p. 186.

position and density are definitely related; since it has been observed, for those rocks having the same mineral composition, the densest have proven the heaviest, least absorptive, generally the strongest, and, as a rule, accordingly, the most durable.

The specific gravities of the Georgia granites and gneisses appended in the table, Chapter VI, were determined by suspension in distilled water, upon carefully selected fragments, weighing from ten to twenty grammes, and from which all included air was previously expelled by boiling, according to the method given by Clarke and Hillebrand.[1] The weight in air, divided by the loss of weight in water, is the specific gravity sought.

Formula

$$\text{Sp. Gr.} = \frac{\text{Weight of Stone in Air}}{\text{Wt. of Stone in Air} - \text{Wt. of Stone in Water}}$$

Weight per Cubic Foot

The weight of stone, expressed in pounds per cubic foot, becomes, at times, of considerable practical importance and convenience. It is obtained by multiplying the specific gravity of the stone by 62.5, the weight in pounds of a cubic foot of water at 4° C. (39.2° F.).

The weight of stone is again commonly expressed by the number of cubic feet contained in a ton (2,000 pounds), and is obtained, by dividing 2,000 by the weight of a cubic foot of the stone, expressed in pounds. The tables of Chapter VI contain the specific gravity, ratio of absorption, weight per cubic foot, and the number of cubic feet in a ton, for the various types of the Georgia granites and gneisses.

Porosity

By porosity is generally meant the amount of pore space in a rock. The method, ordinarily employed for obtaining the porosity, is as follows:[2] The sample is heated to a temperature of 100° C., to expel all moisture. It is then cooled, weighed and immersed in distilled water, where it is allowed to remain, until "bubbles cease to be given off." The surfaces of the specimens are then quickly dried by wiping with bibulous paper, and they are again weighed. The difference in the two weights represents the weight of water absorbed, which, when divided by the weight of the stone dried, represents the porosity.

[1] Bul. No. 148, U. S. G. S., 1897, p. 23. [2] Bul., Wisconsin Geol. Surv., 1898, No. 4, p. 68.

THE COLE QUARRY NEAR NEWNAN, GEORGIA, SHOWING, IN VERTICAL SECTION, GRANITE WEATHERING FROM THE LOOSE SOIL AT THE TOP, THROUGH THE PARTIALLY DECAYED, TO THE FRESH GRANITE, THE DECAY HAVING PROGRESSED ALONG HORIZONTAL LINES.

The following objections are urged against this method by Buckley.[1] All moisture cannot be expelled at the temperature of 100° C. Complete saturation is not produced by immersion, until "bubbles cease to be given off." The result obtained is not the porosity; but it is more aptly termed the "ratio of absorption."

Buckley's method for computing the pore space in the case of the Wisconsin rocks is as follows: Two inch cubes are heated in the air bath at a temperature of 110° C. to uniform weight; and subsequently they are cooled and weighed. The specimens are then immersed in water under pressure, by special device, through the means of an air-pump and bath, and are allowed to remain thirty-six hours, when they are removed; the surfaces, freed from adhering water by bibulous paper; and the specimens, quickly weighed. The difference in the two weights, multiplied by the specific gravity and added to the dry weight, gives the "sum." "The difference of the dry and saturated weights, multiplied by the specific gravity of the rock, [is] then divided by the sum." The result thus obtained, is the actual pore space percentage.

Ratio of Absorption

A discrimination is here made between porosity and ratio of absorption. The former relates to the percentage of pore space, while the latter is "the percentage of the weight of absorbed water to the average weight of the dry sample."[2] By absorptiveness is meant the capacity of the stone to absorb or take up water, from which data the ratio of absorption is deduced. The specimens of Georgia rock, upon which this test was made, were carefully selected, and were roughly cubical in shape, varying from 80 to 140 grammes in weight. The blocks were freed from all sharp edges, corners and deep cavities; and were dried at a temperature of 110° C., to expel all included moisture; and were cooled and weighed. They were then suspended, by means of twine, from a support in a vessel of distilled water, to an approximate depth of five inches, and were allowed to remain, without being disturbed, for exactly forty-eight hours. The temperature of the water remained constant throughout the entire period of immersion.

As soon as removed from the water, each specimen was carefully swabbed, and was allowed to remain on a table in the laboratory for a few minutes, in order to free the block from any possible adhering moisture on its surface; it was then rapidly weighed. The difference in the two weights represents the weight

[1] Bul., Wisconsin Geol. Surv, 1898, No. 4, p. 69. [2] Ibid., p. 372.

of water absorbed. The weight of water absorbed, divided by the weight of stone (dry), is the percentage of absorption.

Formula

$$\text{Percentage of absorption} = \frac{\left\{\begin{array}{l}\text{Wt. of spec. immersed in}\\ \text{water for any given time}\end{array}\right\} - \left\{\begin{array}{l}\text{Wt. of spec.}\\ \text{dry}\end{array}\right\}}{\text{Wt. of spec. dry}} \times 100$$

Heat Test

If sufficient heat is produced, and is continued for a long enough time, any one of the various kinds of building stones will be partially destroyed. Necessarily, this varies for the variety of stone; as the manifold tests, already made, emphasize, that different building stones indicate a great difference in capacity, with which they withstand high temperatures. This test consists generally of carefully selected and prepared samples, of a uniform size. One- to two-inch cubes are usually employed, and are placed in a furnace, and gradually subjected to an intense heat, the registry or degree of temperature being noted by means of the pyrometer. The samples are then removed, and are allowed to cool slowly; or, what is frequently done, cooled rapidly by plunging while hot into cold water. Subsequently, they are carefully examined as to effect. The specimens may be removed from the furnace and examined at any stage during the process.

Freezing Test

The value of this test has long been recognized, and several methods have been devised for carrying out such in the laboratory. In this case, as in others, it becomes necessary to exaggerate more or less largely the real or actual conditions; since, after judicious placement of the stone in a wall, it seldom becomes saturated with water except perhaps at or near "water-line." The test employed may be either natural or artificial. The natural test consists in alternately freezing and thawing, usually in cold storage rooms, the selected samples of stone for the test, the rate and temperature, being left to the discretion of the operator. The artificial test is based upon the principle of inducing internal stresses by means of the crystallization of some absorbed chemical salt by the stone, representing after a fashion the natural freezing of absorbed water. The weighed cubes of stone, of given dimensions, are saturated for a given time with a boiling solution of some prepared soluble salt, generally sulphate of soda, and are allowed to dry. During the drying, the absorbed salt crystallizes and induces stresses somewhat analogous to those induced by frost action.[1]

EXPANSION AND CONTRACTION TEST

This becomes of value in the weathering of stone, and in making the proper allowance for expansion in parapet walls. Col. Totten found in 1832 the rate of expansion per inch for each degree of temperature for granite to be .000004825 inch. The Ordnance Department of the United States Army[2] has made use of the following method: The carefully prepared and measured bars of stone (20 inches long) are placed in baths of cold water with a temperature of 32° F.; thence into boiling water at 212° F.; and back again into cold water. Tests made according to the above method on eleven specimens of granite, from nearly as many different States gave results for the amount of permanent swelling, ranging from .0019 inch in case of California granite, up to .0071 inch in case of Massachusetts stone, with a mean average for the full number of specimens of .0040 inch.

CORROSION TEST

This test is practically of no value in the case of granites, and is seldom applied. It relates chiefly to all calcareous rocks, such as limestones and marbles, and those sandstones, whose grains are cemented together by means of a calcareous cement.

[1] Luquer, Dr. L. McI., Trans. Amer. Soc. C. E., 1895, Vol. 33, pp. 234–247.

[2] Rep't on Tests of Metals, Etc. at Watertown Arsenal, U. S. War Department, 1895, p. 322.

CHAPTER III

PART I

GEOLOGY AND PHYSIOGRAPHY OF THE PIEDMONT PLATEAU

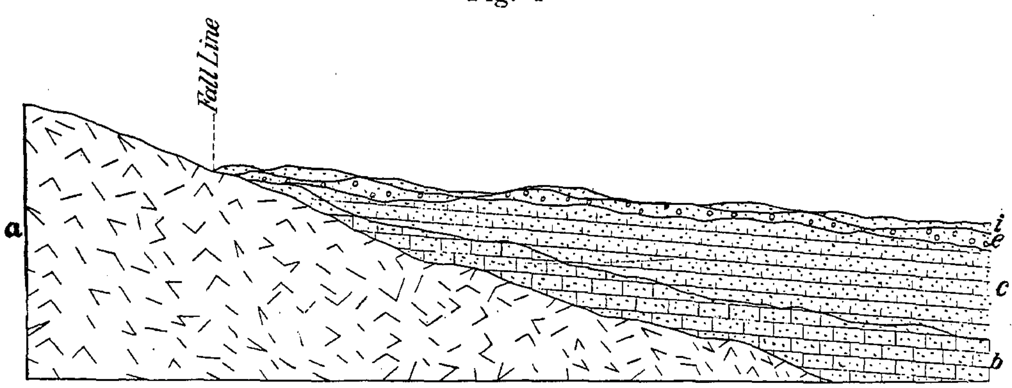
It will be observed, by referring to the map facing page 64, that the State is, broadly speaking, divisible into three geologically distinct areas, which, named in their order from southeast to northwest, are: (a) *the Coastal Plain*, (b) *the Crystalline Belt*, and (c) *the Paleozoic Area*. The three areas are unlike in topography, kind, age and, to some extent, origin of their rock; and they are further differentiated from each other, by somewhat sharp and well defined boundaries. A line, drawn from Augusta through Milledgeville and Macon to Columbus, separates the Crystalline Belt from the Coastal Plain on the southeast. This is an irregular contact, formed by the overlapping of the Coastal Plain sediments on the upturned and highly tilted ancient crystalline rocks of the Crystalline Belt. It crosses the State in an approximate south of west course. On the northwest, the Crystalline Belt is separated from the Paleozoic Group by the "Cartersville Fault." This is a somewhat irregular line, passing south from a point located a few miles east of Cohutta Springs, in Murray county, to the vicinity of Cartersville in Bartow county, and thence bearing south of west to Esom Hill, Polk county, where it passes into Alabama.

Upon physiographic grounds, the so-called Crystalline Belt and the Paleozoic Group are each capable of differentiation into several distinct physiographic provinces, of more or less widely varying character. As previously defined,[1] the Crystalline Belt in Georgia has hitherto included the Piedmont Plateau and the Appalachian Mountains physiographic provinces; while under the Paleozoic Group, has been placed the Georgia equivalent of the Appalach-

[1] C. W. Hayes, Physiography of the Chattanooga Dist. in Tennessee, Georgia and Alabama; 19th Ann. Rept., U. S. G. S. 1897-'98 (1898).

ians' Valley province, and, in the extreme northwestern part of the State, a small area of the Cumberland Plateau province. More accurately speaking then, and without regard to the area of each, the State is divisible, as will be seen by the map facing page 72, into the following five distinct physiographic provinces,[1] which, named in their order from southeast to northwest, are: (a) the Coastal Plain, (b) the Piedmont Plateau, (c) the Appalachian Mountains, (d) the Appalachian Valley, and (e) the Cumberland Plateau. An approximate parallelism with each other and the Atlantic Coast line is observed in these belts, with a general northeast-southwest trend. The Georgia equivalent of each of the belts represents, therefore, their southern extension or prolongation along the eastern border region of the United States.

Fig. 1



Ideal Section Illustrating the Relationship between the Piedmont Plateau and the Coastal Plain. a. Crystalline Rocks (Gneiss, Schist, Granite Etc.). b. Cretaceous Sands, Clays, Marls and Limestone. c. Tertiary Sands, Clays, Marls and Limestone. e. Lafayette Sand, Gravel and Clay. i. Columbia Sands.

The granitic rocks, treated in this report, are entirely within the limits of the Piedmont Plateau province, which is an elevated belt of country, having a northeast-southwest extension along the eastern base of the Appalachian mountains, and disappearing under the Coastal Plain sediments on the southeast. It occupies the middle northern portion of the State. The Plateau differs markedly from the Coastal Plain in the nature and origin of its surface features and the age and kinds of rock. The almost horizontal beds of the Coastal Plain, including strata ranging in age from Cretaceous upward, lie unconformably across the bevelled edges of the highly tilted and disturbed crystalline rocks of the Plateau. The line of

[1] Hayes, C. W., Physiography of the Chattanooga District in Tennessee, Georgia and Alabama; 19th Annual Report, U. S. Geol. Surv., 1897-98 (1898), pp. 1-59; especially pp. 11-13.

contact between the two provinces was early recognized and known as the "Fall Line." Owing to the difference in geologic conditions in the two provinces, the traversing streams undergo a marked transition along this line.

The transition in the rocks of the Plateau on the northwest to the highly metamorphosed and folded strata of the Appalachian region is less distinctly marked, and by no means so sudden, as the change from the Coastal Plain. The Piedmont region is characterized as an undulating or rolling plain, with an altitude along its western edge of about 1,000 feet, and sloping gradually seaward, with an elevation along the Fall Line, or the Plateau's eastern limit, of 250 to 300 feet. Residual masses of unreduced areas, such as Kennesaw, Lost and Stone mountains, rise several hundred feet above the general level of the upland surface of the Plateau.

A close examination of the map further discloses the fact, that the major streams of the Plateau preserve a general parallelism, in their courses across the Piedmont Plain; and with the single exception of the upper course of the Chattahoochee river, the general trend of the major streams is approximately at right angles to the northeast-southwest course of the Plateau. The streams have apparently maintained their courses across the Plain, regardless of the foliation and differential hardness of the rocks. They have cut through the deep mantle of soil and decayed rock, and frequently into the fresh and harder rock beneath, resulting in the cutting of deep and narrow valleys, in the upland surface, and preserving low and more or less rounded hills and ridges of slight and gentle curvature among the interstream areas. With the exception of the Savannah and Chattahoochee rivers, the trunk streams all head within the limits of the Plateau. These two have encroached upon the Appalachian's territory, by pushing their headwaters into its area. The Chattahoochee heads near the Carolina line, and flows, in nearly a southwest course, across the Plateau, when, near the middle-south portion of the Plateau at the Alabama line, it turns southward and continues to the Gulf, marking from this point the boundary between Georgia and Alabama. As shown by Campbell,[1] this stream presents an unsymmetrical aspect, with reference to its tributaries. Since the establishment of the minor drainage features on the Plateau, some have, on account of more favorable conditions, encroached upon the northeast drainage area of the Chattahoochee, by pushing the divide headward into its territory.

Campbell has further shown a strong southeast slope for the

[1] Drainage Modifications and Their Interpretation; Journal of Geology, 1896; Vol IV, pp. 672-673.

Plateau, since its elevation in middle Mesozoic time. This slope has enabled the minor drainage lines to establish straight and regular courses at right angles to the main course of the Chattahoochee, but forming in the basins of the other trunk streams a symmetrical drainage, of the normal dendritic type.

This condition has, in geologically recent time, facilitated the capture of the head-waters of the Chattahoochee by one of the Savannah tributaries in the region of Tallulah Falls;[1] and in the vicinity of Gainesville, a second capture is imminent; as at one point one of the streams has extended its course headwards, within a short distance of the Chattahoochee, whose elevation is given by Campbell, as 100 feet below that of the Chattahoochee.

The western drainage portion of the Piedmont Plain, skirting the base of Pine Log Mountain near Cartersville, lies wholly within the drainage of the Etowah basin.

The Rocks and Structure of the Plateau

The Piedmont Belt is composed of completely holo-crystalline rocks, which afford at present but little evidence of ever having been deposited as sediments. Whatever may have been their origin and structure in the beginning, they have been subjected to so many vicissitudes of profound dynamic metamorphism, mainly through pressure and re-crystallization, that proof of sedimentation is scant. This metamorphism has induced a secondary foliation in the rocks, by arranging the mineral constituents along parallel lines, which evidently bear little or no relation to the possible original bedding planes in many of these rocks.

The rocks consist principally of granites, gneisses and schists, cut by a series of younger basic eruptives, principally diabases and diorites. Along the northwestern limits and in other parts of the Plateau, a belt of basic ferro-magnesian silicate rocks, containing the corundum deposits, are found crossing the State in an approximately parallel direction with the axis of the Piedmont Plateau; and they have been classed as eruptive rocks by King.[2] Along the eastern, middle northern and southwestern parts of the Plateau, are found belts of quartzite and, in some places, limestone.

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[1] Hayes, C W., and Campbell. M. R., The Relation of Biology to Physiography; Science, 1900; Vol. XII (N. S.), pp. 131-133. Davis, W. M., Current Notes on Physiography — Tallulah Gorge, Georgia; Science, 1901, Vol. XIII (N. S.), p. 871. Jones, S. P., The Geology of the Tallulah Gorge; Amer. Geol., 1901, Vol. XXVII, pp. 67-75.

[2] A Preliminary Report on the Corundum Deposits of Georgia, Geol. Surv. of Georgia, 1894, p. 133.

Throughout the Plateau region the rocks have a prevailing southeast dip, approximating 50°; and strike from 20° to 30° west of south. Local variations, however, in both dip and strike are wide-spread and marked, over the region.

At present, nothing can be said definitely concerning the origin of the schists of the Piedmont region; but it is certain that all the granites and gneisses thus far studied are of igneous origin, and represent several periods of intrusion.

Soils of the Piedmont Plateau

Throughout the Piedmont region in Georgia, and, in fact, the entire area of the South Atlantic Border States, the bed-rocks are mantled with a deep and heavy covering of vari-colored residual decay. Outcrops of the fresh rock occur along the valleys and stream courses, where the latter have sunk their channels below the depth of residual decay. In the granitic portions of the belt, low, flat surfaces and dome-shaped masses of fresh granite are exposed in the inter-stream areas, where removal has kept pace with decay. In a general way, color serves as a basis of division of the soils into (a) red and (b) light-gray. As shown in a subsequent part of this report,[1] the distribution of these soils and the chemical decomposition over mechanical disintegration of the iron-bearing silicates are the main factors controlling the color.

As one of the criteria for the recognition of such a base-leveled plain (Piedmont Plateau), Davis says:[2] "—— the deep soils of the upland plain and the rocky walls of the narrow steep-sided valleys are as important witnesses to the once lower position of the plain and to the uplift by which its present altitude has been gained as are the forms of the upland and the valleys."

RÉSUMÉ: To recapitulate, the Piedmont region must be considered as an old, dissected and base-leveled upland, whose present altitude has enabled the streams now active, to incise rather deep and narrow channels through the covering of decayed rock and oftentimes into the hard rock beneath. Without stating the reasons, the plain has been shown to pass through at least two periods of base-leveling; one in Cretaceous, and the other in Tertiary time. These two plains in the Georgia portion of the Plateau practically coincide, and are not readily visible as separate plains. Only a few unreduced residuals, of small dimensions, rise above the old base leveled upland, whose surface, while not entirely featureless, is one of broad and gentle undulations, with a distinct and gradual seaward slope.

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[1] Chapter V, Part 2.

[2] The Peneplain, by W. M. Davis, Amer. Geol., Vol. XXIII, No. 4, 1899, pp. 214-215.

FIG. I. PHOTO-MICROGRAPH OF A PHENOCRYST OF MICROCLINE, SHOWING INCLUSIONS OF QUARTZ AND OF OTHER FELDSPAR SPECIES.

From Porphyritic Granite, from the McCollum Place, near Coweta Station, Coweta County, Georgia. Crossed Nicols x 74.

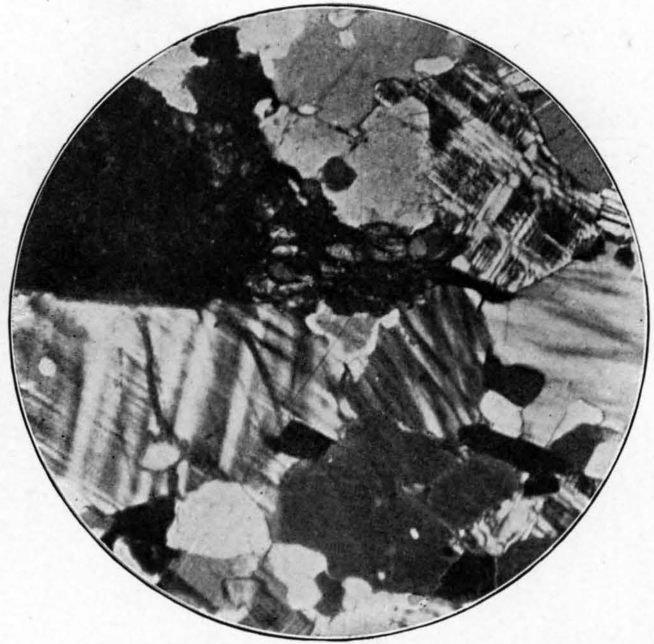


FIG. 2. PHOTO-MICROGRAPH OF BLUE-GRAY GRANITE, FROM THE CARMICHAEL QUARRY, NEAR FAIRBURN, CAMPBELL COUNTY, GEORGIA.

Crossed Nicols x 74.

Concerning the Plain, farther north in Virginia, McGee says:[1] "—it must be regarded as the basal portions of a vast mass of inclined rocks, of which an unmeasured upper portion has been planed away."

Age of the Piedmont Plateau Rocks

Definite differentiation and correlation of the rocks forming the Piedmont Plain in Georgia are yet in an unsettled state, so far as they are based on detailed work. They have not been assigned, except in a very general way, to any definite horizon or horizons in the geological time-scale. Thus far, all workers are agreed in calling them pre-Paleozoic rocks. So far as the writer's work on the granitic type of rocks within the province is concerned, they represent different periods of intrusion, and cannot, therefore, be assigned the same relative age.[2] In every case studied, they have been found to intrude upward into the older schistic rocks, and have been exposed at the surface by means of erosion.

PART 2

DESCRIPTION OF INDIVIDUAL PROPERTIES

HEARD COUNTY

Heard county lies immediately west of Coweta county, next to the Alabama State-line. Extensive areas of foliated granite and gneisses, of good quality, are found in various portions of the county; but, due to the lack of transportation facilities principally, none of the outcrops have been worked, save for local use in the county. In driving from Newnan, the county-seat of Coweta, to Franklin, the county-seat of Heard, in a southwesterly course, a distance of nearly twenty-five miles, the prevailing rock crossed is gneiss. The most extensive granite exposure in the county occurs three miles southwest of Franklin, which, on

[1] Nat. Geogr. Mag., Vol. VIII, 1896, p. 263.

[2] No facts have thus far been found, discrediting in any wise the belief, that the latest of the granitic masses in the Georgia region are pre-Paleozoic in age.

account of its extent and manner of outcrop, is known as "Flat-rock."

THE FLAT-ROCK QUARRY.—This extensive body of rock occurs three miles southwest from Franklin, the county-seat of Heard county, and includes, at the lowest estimate, 400 acres in one continuous flat-surface outcrop, the relief of which is broken here and there by knolls of slight elevation. The rock is owned by a number of individuals, the following among whom are the principal: T. B. Redmond and A. J. Kitchens, Texas, Georgia; J. O. Kirk, Viola, Georgia; and Miss M. E. Lasby, Franklin, Georgia. The remainder of the property is controlled by a large number of individuals, who own only a few acres per person.

More or less rock has been quarried at places over the outcrop, for the past forty years. A shop stands near one edge of the rock-exposure, where stones for local monuments have been shapened and polished, and inscriptions chiseled in them, for the past thirty or forty years. A number of grave-stones had been completed, and were ready to be placed in the cemeteries, at the time of the writer's visit, which revealed not only the good quality of the work done with the limited appliances at hand, but attested the excellent grade and the superior working qualities of the rock, as well. In all, there have been seven openings made, indicating the removal of a considerable quantity of rock from some. It has been used principally for monuments and grave-stones, and for building purposes in Franklin, where some of the stone was used in the construction of the county-jail and the new court-house, recently built. Parts of the outcrop are well set, in a heavy growth of excellent pine timber.

The rock is a fine-grained, foliated biotite granite, in which the component minerals, quartz, feldspar and biotite are readily distinguished by the unaided eye. Each of these minerals apparently occupy well defined areas in the hand specimen. The mica has a dull, grayish-black tone, and is distributed along roughly parallel lines through the rock, in areas of grouped shreds, which vary from 2 to 20 millimeters in diameter, imparting the characteristic foliated structure seen in the hand specimen. When broken at angles to the foliation, the parallel arrangement of the mica is quite marked; but, when split along the foliation, the mica areas appear to be irregularly distributed through the groundmass, as it were, of the light-colored minerals, quartz and feldspar, imparting somewhat of a porphyritic appearance to the rock. This distribution of the biotite, in the perfectly white granulated and lively appearing feldspars and quartz, give the rock a decidedly speckled, but pleasing look.

Microscopically, the rock (Museum No. 1,894) is made up of complexly interlocking grains of quartz, microperthitic orthoclase, and about equal portions of microcline and plagioclase, with a few stout, aggregated shreds of biotite occasionally intergrown with muscovite filaments. In size and crystal outline, the minerals are inequidimensional and wholly allotriomorphic. Irregularly rounded quartz grains are usually enclosed as drop-like inclusions in the larger feldspar individuals. The schistose structure is not apparent under the microscope, and the rock texture is allottriomorphic-granular, as contrasted with idiomorphic-granular. The biotite is partially altered to chlorite. A few microscopic grains of garnet, with a reddish cast and without crystal outline, are present.

Dynamo-metamorphism is shown under the microscope in the partial peripheral shattering of the quartz and feldspar; lines of fracture; and irregular double-refraction, common to the larger quartz and feldspar grains.

A chemical analysis of specimens of this rock in the Survey laboratory gave the writer the following results:—

Silica, SiO_2	74.96
Alumina, Al_2O_3	13.71
Iron Sesqui-oxide, Fe_2O_3	0.90
Lime, CaO	1.02
Magnesia, MgO	0.24
Soda, Na_2O	4.68
Potash, K_2O	4.79
Ignition	0.44
Total	100.74

The above analysis indicates a highly siliceous rock with a low percentage of iron, lime and magnesia. The potash and soda, it will be observed, appear in approximately equal proportion. A comparison of this analysis with analyses of the granite-gneisses from DeKalb, Gwinnett and Rockdale counties shows very close agreement.

Other tests made yielded the following figures:—

Specific gravity at 19° C.	2.648
Weight of one cubic foot of stone expressed in pounds	165.50
Number of cubic feet of stone contained in one ton (2,000 pounds)	12.0

A careful examination of the natural outcrop of this rock in the field, where it has been exposed to the attack of the atmospheric forces for an indefinite time, geologically speaking, shows, that it resists, to a remarkable degree, the agents of disintegration and decomposition. The sap—partially decayed surface rock—is exceedingly thin over all parts of the rock surface. No imperfections or blemishes of any character were observed in the natural exposure of the rock.

A survey made in 1890 of an extension of the Chattanooga, Rome and Southern railroad by way of Carrollton to Columbus, Georgia, passed within one and one-half miles, east, of the above granite area.

THE WYNN QUARRY.—This quarry is owned by Messrs. J. M. Buttrell, of Hogansville, and S. B. Heard, of Franklin, Georgia. The quarry is located in an extensive ledge outcrop of rock, exposed along a very steeply sloping hillside, approximately 500 yards, slightly east of south, from the county court-house building. The rock quarried has been used for building purposes in the town of Franklin.

In the hand specimen, this is the same rock as that described above at "Flat-rock," three miles southwest from Franklin, except that the metamorphism has progressed a little further, and resulted in producing a thin, but distinctly laminated or banded granite-gneiss. In addition to the quartz, feldspar and biotite, numerous scattered small grains of red garnet are distributed through the hand specimen.

A microscopic study of a thin section of this rock (Museum No. 1,893) reveals an allotriomorphic-granular rock, in which the laminated or schistose structure is not visible. The rock is a biotite granite-gneiss, composed of the mineral species, quartz, orthoclase with microperthitic intergrowths of albite, microcline and plagioclase, with single scattered foils of biotite. Good cleavage is observed in some of the orthoclase individuals. Plagioclase is less abundant than microcline. The usual quartz and feldspar grains are enclosed as drop-like inclusions by the larger individuals of these minerals. Some chlorite, muscovite and epidote are present as derived or alteration products. Lines of fracture and undulous extinction, common to the large quartz and feldspar anhedra, and the fine-grained mozaics of these minerals, are suggestive of the effects of strong dynamo-metamorphism.

Outcrops, in boulder and ledge form, of granitoid rock, are continuous from the Coweta-Heard county-line into Franklin, along the Newnan-Franklin wagon-road. The residual decay of this rock-type along the roadside reaches, oftentimes, depths of 40 to 50 feet in exposed vertical section, consisting for the most part of stiff red and yellow, and less frequently, mottled clays.

A belt of dark-blue hornblende gneiss, similar to that occurring in Meriwether, Troup and Gwinnett counties, outcrops across the Chattahoochee river from Franklin.

TROUP COUNTY

Troup lies immediately south of Heard county and next to the Alabama line. Several areas of gneiss are found in the county, some of which have been worked to a limited extent.

One and one-half miles west from LaGrange, on Moore's place, ledge outcrops of a fine-grained gneiss occur along a small stream known as Moore's branch. Some of the rock has been quarried for street paving, foundations and retaining-walls in LaGrange. It is a fine-grained, vari-colored and irregularly banded biotite granite-gneiss. The layers vary in thickness, and from dark-gray to nearly white in color, according to the amount of biotite present.

A thin section of rock (Museum No. 1,904) from one of the dark-gray layers, indicates, under the microscope, a very fine-grained, allotriomorphic-granular rock, composed principally of quartz and orthoclase, with some microcline and plagioclase present, and an abundance of small plates of biotite, completely altered to a dark greenish-brown opaque chlorite without crystal outline. Quartz is the predominating mineral present. From the few scattered, ragged-outline crystals of quartz and feldspar in the thin section, the rock affords some evidence of having been at one time a coarse-grained granite, subsequently subjected to profound metamorphism and reduced almost entirely to a mozaic of fine-grained, interlocking quartz and feldspar, which exhibit marked undulous extinction between crossed nicols.

A similar examination of a thin section under the microscope of a specimen (Museum No. 1,905) from one of the white and nearly biotite-free layers of the same rock, reveals the same fineness in grain and texture; but it contains nearly equal proportions of microperthitic orthoclase and microcline, while the amount of plagioclase remains practically the same as for the dark layer (Museum No. 1,904), and it contains a greatly decreased amount of biotite. The orthoclase species of feldspar also contains increased microperthitic intergrowths with a second feldspar in the light-colored layer. The light- further differs from the dark-colored layer in showing an excess of the feldspar constituent over the quartz.

Outcrops of the same rock occur from three-quarters to a mile west of LaGrange, and are more or less continuous from this point to the opening described above.

A dark-blue colored and finely banded hornblende-gneiss, similar to that occurring in Meriwether, Heard and Gwinnett counties, described elsewhere in this report, outcrops in several places near the corporate limits of LaGrange. Several of these have been opened, and the rock used for foundation and other rough work in the town.

THE MOUNTVILLE QUARRY. — Located a quarter of a mile from, and on the north side, of the Macon and Birmingham railroad, eight miles east of LaGrange, and one mile west of Mountville, is an extensive outcrop of contorted biotite granite-gneiss. The exposure includes three to four acres of flat surface rock. One surface "raise" has been made in the outcrop, and some rock has been quarried for street purposes. The rock is easily worked, readily accessible, and is an excellent grade of material for street purposes. It represents the westward extension of the large body of contorted biotite granite-gneiss, crossing Meriwether county in an east and west direction from Odessa to Woodbury. This area of contorted granite-gneiss is similar in every respect to the Lithonia belt in DeKalb county.

In the hand specimen (Museum No. 1,892), the rock is a light-gray, medium-grained, irregularly banded, contorted biotite granite-gneiss, carrying a few scattered grains of magnetite in places.

Microscopically, it is a massive granular, fine-grained rock, without trace of the schistose or laminated structure shown in the thin section. It is composed of complexly interlocking anhedra of quartz, microperthitic orthoclase, microcline and plagioclase, with biotite plates more or less altered to chlorite and epidote. Quartz is the predominating mineral. It contains numerous fracture lines, and, in addition, displays the characteristic undulous extinction between crossed nicols. The relative abundance and proportion of the feldspar species present in the rock is orthoclase $>$ microcline $>$ plagioclase. The larger individuals of feldspar and quartz contain abundant microscopically enclosed grains, of varying dimensions and rounded outline, of the same minerals. Small areas of crushed fine-grained quartz and feldspar, partially surround the larger grains of these minerals, and, in most cases, are quite numerous. Microscopic inclusions of zircon and apatite and a few idiomorphic crystals of magnetite, complete the list of minerals present. A comparative study of a thin section of the rock with that from the Lithonia belt of contorted granite-gneiss in DeKalb county, reveals the practical identity of the two rocks.

MERIWETHER COUNTY

Extensive areas of fine- and even-grained biotite granite-gneiss, of excellent quality, well suited as monumental and general building stone, and for street work, in the form of Belgian blocks and curbing, are found in Meriwether county. The granitic rocks of Meriwether, which as stated above, consist of true granites and gneisses, are intimately associated in occurrence; but they are not of the same age, as is shown in a subsequent part of this report. They may, however, for convenience of statement, be grouped and defined at present as one continuous belt, extending in an easterly course from near Mountville in Troup county, the most westerly outcrops, entirely across the central portion of the county into Pike county on the east, including the Odessa, Greenville, Harris City, Woodbury and Flint river granitic areas. A number of quarries have been opened at various points over the belt, and a rather large supply of stone has been quarried from some.

Granites

The true granites occurring in Meriwether county are massive, and fine- to medium-grained in texture; dark-gray in color; and intimately associated with the contorted granite-gneisses described below. The relationship of the massive granites and the contorted granite-gneisses is discussed in a subsequent part of this report.

The A. M. Hill Place. — Two and a half miles from Greenville, are boulder outcrops of a dark-gray granite, extending over some eight to ten acres, along the course, and near the headwaters, of Red Oak creek. As traced, the belt has apparently a northeast-southwest course, with an approximate length of two and a half miles, and is from one to three quarters of a mile wide. The most southwesterly outcrop of this rock occurs in front of the Strozier dwelling (old Jackson place), four miles west from Greenville. The belt crosses lots of land owned by the following persons: Messrs. A. M. Hill, O. Ward, G. J. Martin, J. M. Terrell, and the heirs to the Jackson estate.

Megascopically, the rock is a medium-grained, dark-gray biotite granite, of excellent quality. The writer was informed by Mr. Hill, that the rock is susceptible of a high polish, which is certainly in full accord with specimens of a similar rock occurring on Mr. T. B. Tigner's place, which show a very high polish.

Microscopic study of a thin section from a specimen of this rock (Museum No. 1,869) revealed a medium-grained rock composed of the potash feldspar species, microperthitic orthoclase and microcline, with quartz, some plagioclase and large, stout aggregated plates of brown colored and strongly absorbing biotite. An abundance of large grains of a brownish colored, slightly pleochroic epidote, with irregular crystal outline, occurs. This granite shows, on chemical analysis, an increased percentage of lime (CaO) over that of other granites found in the State. The feldspar and quartz grains are allotriomorphic in outline, and are further characterized by the usual inclusions, with marked zonal structure, common to the feldspars. Biotite occurs, more or less altered to a dark, opaque chlorite, and is associated with occasional foils of muscovite. Prismatic inclusions of apatite are somewhat numerous and large in size. The quartz anhedra contain extremely fine and greatly drawn out thread-like filaments, which could not be definitely identified, but which are probably rutile. Peripheral shattering of the larger quartz and feldspar grains, marked irregular double-refraction, and lines of fracture common to the quartz, indicate the usual mechanical strain.

A chemical analysis of specimens of this rock, in the laboratory of the Geological Survey, gave the writer the following results: —

Silica, SiO_2	62.52
Alumina, Al_2O_3 / Iron Sesqui-oxide, Fe_2O_3	23.58
Lime, CaO	3.24
Magnesia, MgO	1.55
Soda, Na_2O / Potash, K_2O	8.57[1]
Ignition	0.54
Total	100.00

A comparison of this with the analysis of the Tigner granite[2] shows the two rocks to be essentially the same. The Hill and Tigner granites show a smaller percentage of silica and a proportionately increased percentage of alumina, iron, lime and magnesia over that of the finer-grained biotite granite quarried by the Greenville Granite Company near Greenville. The total percentage of alkalies is approximately equal in each case.

The properties of the Hill granite render it especially suitable and desirable as a monumental stone.

The color of the partially weathered portion of this granite is a light yellowish brown, due to the partial decomposition of the biotite. The weathered specimen is still hard and firm rock, in which the black mica (biotite) is highly lustrous, and the feldspars are more or less dull and opaque, from partial kaolinization.

Other tests, made on specimens of the rock, yielded the following results: —

Specific Gravity	2.731
Weight of one cubic foot of stone expressed in pounds	170.68
Number of cubic feet of stone contained in one ton (2,000 pounds)	11.7

[1] By difference.

[2] See p. 74.

Fig. 1

Fig. 2

PORPHYRITIC GRANITE, NEAR PALMETTO, GEORGIA.

Fig. 1. Fractured Surface of a Partially Worked-up Boulder, Showing the Texture of the Rock.

Fig. 2. Eroded Surface of the Residual Clay, from the Porphyritic Granite.

These figures may be compared with the similar ones obtained from tests made on specimens of rock from the Tigner quarry.

THE T. B. TIGNER QUARRY.—This quarry is located in the 7th district, approximately six miles slightly south of west from Greenville, two miles from Odessadale, and half-a-mile south of the nearest point to the Macon and Birmingham railroad. The rock outcrops as large boulders over an extensive wooded slope on the two sides of the public wagon-road. Several boulders have been worked up, on the east side of the road in the pine woods. A polished specimen of the granite was shown the writer at Mr. Tigner's house, which was eminently satisfactory. The excellent finish, which this stone is susceptible of taking, both polished and hammer-dressed, is well shown in an eight-inch cube on exhibition in the State Museum in the State Capitol building in Atlanta. The few stones quarried have been used for local purposes. The first opening was made in 1891.

Megascopically, the rock is a medium-grained, dark blue-gray biotite granite, of excellent quality, and admirably suited for monumental stock.

A thin section of the rock (Museum No. 1,872), studied under the microscope, revealed an allotriomorphic-granular biotite granite. It is composed of the feldspar species, microperthitic orthoclase, microcline and a good proportion of plagioclase, with quartz and large aggregated plates of biotite, intergrown with occasional muscovite foils. Like the similar granite found on the A. M. Hill place, a large proportion of a brownish colored, slightly pleochroic epidote, of large size grain, usually of very irregular crystal outline, occur; though several idiomorphic crystals were observed in the thin section. Evidence points to this mineral's being a derived product, and not an original mineral, from the interaction of the feldspar and biotite. Plagioclase is fairly abundant, and is present as stout, lath-shaped crystals, polysynthetically twinned. Biotite occurs as large, grouped plates, with marked basal cleavage, strong absorption, and brown in color, containing some inclusions, and partially altered to chlorite. Somewhat large prismatic inclusions of apatite are quite numerous. The larger quartz and feldspar grains are crossed by numerous lines of fracture.

The composition of this rock is shown in the chemical analysis below, made by the writer in the laboratory of the Geological Survey:—

Silica, SiO_2	63.27
Alumina, Al_2O_3	19.93
Iron Sesqui-oxide, Fe_2O_3	2.82
Lime, CaO	2.89
Magnesia, MgO	0.49
Soda, Na_2O	4.14
Potash, K_2O	4.85
Ignition	0.86
Total	99.25

It will be observed from the field and laboratory descriptions of this rock, as given above, that it is essentially the same granite as that described from the A. M. Hill property. Hand specimens of the rock from the two localities cannot be distinguished.

Other tests made on this rock yielded the following figures:—

Specific Gravity	2.739
Weight per cubic foot of stone expressed in pounds	171.18
Number of cubic feet of stone contained in one ton (2,000 pounds)	11.6

THE GREENVILLE GRANITE COMPANY'S QUARRY.—This quarry is located just beyond the corporate limits of Greenville, approximately one mile northeast from the county court-house. The quarry is worked under the control of the following gentlemen from Greenville, Georgia, who compose THE GREENVILLE GRANITE COMPANY: Dr. E. B. Terrell and Messrs. B. O. and A. M. Hill.

The quarry was leased, for a period of three years by the above company, from Mrs. Mary Robertson on a royalty. Since the quarry was first opened, the first lease has expired; but it has been renewed for a second period. The stone quarried has been used principally for cemetery and building purposes in Columbus, Georgia. St. Luke's church in Columbus was partially built of stone from this quarry. The rock outcrops as boulders over an extensive area, which are imbedded in a prevailingly stiff, red residual clay. One opening has been made, and worked to an approximate depth of 30 feet along the quarry face.

Megascopically, the rock is a medium-fine and even-grained, dark blue-gray biotite granite, of excellent quality, and is superior as a monumental stone. Scattered shreds of muscovite show up in the hand specimen. Feldspar crystals, averaging five millimeters in length and two in width, tabular parallel to the clinopinacoid (010), and twinned according to the Carlsbad law, are beautifully shown in specimens of the rock.

Under the microscope, a thin section from a specimen (Museum No. 1,866), revealed a medium fine-grained allotriomorphic-granular rock, composed of quartz and the potash feldspars, orthoclase and microcline, with some plagioclase and biotite intimately associated with muscovite shreds. The potash feldspars constitute the most abundant mineral constituents present, showing Carlsbad twinning and microperthitic intergrowth with a second feldspar, albite. Single plagioclase individuals are scarce. An unusually large proportion of rounded quartz and feldspar microscopic, drop-like inclusions characterize the larger grains of these minerals. The quartzes contain, in addition to the inclusions of prismatic apatite, long drawn out and fine thread-like filaments of rutile. Biotite is present as single and grouped plates exhibiting the usual brown color and strong absorption, and carrying inclusions. It is somewhat altered to chlorite, and is partially intergrown with a good proportion of large shreds of colorless, but slightly pleochroic muscovite. Prismatic inclusions of zircon are also common to some of the component minerals present.

Analysis of specimens of the fresh and decayed granite from this locality yielded the writer, in the laboratory of the Geological Survey, the following results: —

	I	II	III	IV
Silica, SiO_2	69.88	54.57	51.29	48.35
Alumina, Al_2O_3	16.42	25.90	29.69	28.03
Iron Sesqui-oxide, Fe_2O_3	1.96	4.69	6 33	4 75
Lime, CaO	1.78	0.05	0.07	3.97
Magnesia, MgO	0.36	0.21	0.14	3.45
Soda, Na_2O	4.46	2.16	1.12	5.35[1]
Potash, K_2O	5.63	2.87	1.50	
Ignition	0.36	10.14	10.36	6.10
Total	100.85	100.59	100.50	100.00

I Analysis of fresh granite.
II Analysis of decayed granite taken 10 feet below the surface.
III Analysis of decayed granite taken 5½ feet below the surface.
IV Analysis of partially decayed granite, collected from the Greenville-Griffin public road between the bridge and Greenville.

Recalculating the figures under columns I, II and III to a basis of 100, and assuming the iron to be constant, a total percentage loss for the entire rock, of 61.85 per cent.,[2] is shown, in passing from the fresh rock to the stage of decay indicated in column II. In the same way, a total loss for the entire rock, of 71.82 per cent. is represented, in passing from the fresh rock to the stage of decay indicated in column III. These changes clearly mark the action of chemical forces in reducing the fresh rock to a highly ferruginous, stiff, red clay.[3]

[1] By difference.
[2] For method of calculation, see Chapter V, Part 2.
[3] For a detailed discussion of the changes incident to the weathering of this rock, see Chapter V, Part 2.

Other tests made gave the following figures : —

Specific Gravity	2.662
Weight of one cubic foot of stone expressed in pounds	166.37
Number of cubic feet of stone contained in one ton (2,000 pounds)	12.0
Percentage (ratio) of absorption	0.086

The rock from this quarry resembles very closely that quarried in the Oglesby blue granite area in Elbert county, described elsewhere in this report. In chemical and mineral composition, the two rocks are apparently identical. The Oglesby granite is a shade darker in color, and slightly finer in grain, than the Greenville rock. Specimens of the polished and hammer-dressed granite from this quarry were shown the writer in Greenville. They very forcibly illustrated the excellent finish, the stone is capable of taking. The properties of this granite should make it a most desirable stone for monumental stock.

The rock weathers finally, to a deep red, highly ferruginous, stiff clay, reaching to a depth of many feet, through which are occasionally distributed boulders of the nearly fresh granite. The exposed surfaces have been deeply trenched and furrowed by the falling waters, until a depth of fifty feet is reached in extreme cases.

FLAT SHOALS.—An extensive exposure of foliated granite, extending for some distance along Flint river, in both Meriwether and Pike counties, occurs twelve miles east of Greenville, and approximately the same distance west from Zebulon, the county-seat of Pike, at Mr. D. N. Freeman's mill. The granite outcrops extend for some distance back from the river, on the Meriwether side of the stream. The same rock is said to outcrop two and a half miles slightly south of east from this exposure, at Neal's station on the Southern railway, in Pike county. A few rocks were gotten out some years ago for mill and bridge piers, which includes all the work done in this section, in the way of granite quarrying.

Megascopically, this is a medium-grained, light-gray, distinctly foliated, biotite granite, in which the component minerals, quartz, feldspar and biotite, are readily, recognizable by the unaided eye.

A thin section of the rock (Museum No. 1,877), examined under the microscope, indicates a medium-grained, allotriomorphic-granular granite, without trace of laminated or schistose structure visible. It consists of quartz, microperthitic orthoclase, microcline and plagioclase, with biotite. The quartz usually occurs as large anhedra occupying well defined spaces. They are crossed by lines of fracture, and exhibit wavy extinction. The feldspar constituent consists as above stated, of the following, named in the order of their abundance: Microperthitic orthoclase, plagioclase with small extinction angle measured on the lamellæ in basal section, and microcline. Peripheral zones of finely crushed grains of quartz and feldspar are frequently observed about the borders of the larger grains of these minerals. Prismatic inclusions of apatite and zircon are very common to the feldspar and quartz anhedra. Chlorite, muscovite and epidote are present in the usual proportions, as derived, or secondary products, from the biotite and feldspar constituents.

The chemical composition of this rock is shown in the following analysis, made by the writer, in the laboratory of the Geological Survey:—

Silica, SiO_2	74.80
Alumina, Al_2O_3	15.46
Iron Sesqui-oxide, Fe_2O_3	1.04
Lime, CaO	0.82
Magnesia, MgO	0.11
Soda, Na_2O	4.80
Potash, K_2O	2.52
Ignition	0.31
Total	99.86

The small percentage of lime, and the large increase of soda, over the potash content, points to albite as the species of the plagioclase feldspar present. This is further confirmed by the optical properties of the plagioclase individuals present in the rock, which were studied in a thin section of the granite under the microscope.

Granite-Gneiss

The gneisses may be readily distinguished in the field from the typical massive granites, by their marked schistose structure, the layers of which are usually considerably contorted. In mineral and chemical composition, the two types of rock cannot be distinguished so readily, inasmuch as they are practically identical.

Mrs. M. J. Hill's Property. — Two miles west from Greenville, the county-seat of Meriwether, occur flat-surface and boulder outcrops of a contorted, light-gray biotite granite-gneiss, extending over approximately ten acres. None of the rock has been quarried; but it is an excellent stone for street pavements, in the form of blocks and curbing, and can be easily worked. The rock has a decidedly pinkish cast in places, due to the pink color of a part of the feldspathic constituent.

One and a quarter miles south from the above exposure, and two miles southwest from Greenville, occur outcrops of a similar character and of the same rock, over some twenty-five acres of a gently sloping hill. The rock has been opened at one point, and some of the stone has been quarried. It is well suited to the various kinds of street work. Hand specimens of the rock show a highly contorted, light-gray biotite granite-gneiss, with a decided pinkish cast, resulting from the color of the feldspar. Scattered grains of pyrite and veins of pegmatite were observed in places along the quarry face, but not to a damaging extent.

A microscopic study of a thin section of this rock (Museum No. 1,868) indicates a fine-grained, allotriomorphic-granular granite-gneiss, with a roughly schistose structure, apparent. It is composed of complexly interlocking grains of quartz and the potash feldspars, orthoclase and microcline, with plagioclase and small foils of biotite. The quartz and feldspar grains are extremely irregular in outline, and display no tendency to idiomorphism. Dynamo-metamorphism is strikingly manifest in the thin section, in long drawn out and roughly parallel crushed areas of fine-grained quartz and feldspar.

THE ODESSA QUARRY.—This quarry is located six miles west from Greenville in the 7th district, and half-a-mile north from Odessadale on the LaGrange-Greenville wagon-road. At the lowest estimate, there are apparently 15 acres of sheet or flat-surface rock in the quarry exposure. The quarry is located in an outcrop, with a moderate slope toward a small stream occupying the valley bottom below, which facilitates easy working. Approximately one and a half to two acres have been stripped, and worked to a depth of eight to ten feet, which includes some four to six sheet "raises" in superposition. Work was first begun about six years ago, and continued through a period of three years, with no quarrying done since, the Georgia Quincy Granite Co., of Macon, being the operators. The stone quarried was used principally for river-work by the United States Government in the St. John's river, Florida, and for street paving in the form of Belgian blocks. A side-track was in operation at the time of working, from the quarry to the Macon and Birmingham railroad at Odessadale. Large quantities of the stone have been quarried.

The rock is an irregularly banded, highly contorted, light-gray biotite granite-gneiss, of a most excellent grade, and admirably adapted to the various kinds of street work. It is in every respect the same rock as that quarried at Lithonia in DeKalb county. Hand specimens of the rock from the two localities cannot be distinguished. It is a continuation of the same rock-mass as that described on Mrs. M. J. Hill's place, and differs from it only in the feldspar's being entirely white, while the Hill rock has a decidedly pinkish cast. The quarry area is cut by veins of pegmatite and dikes of a finer-grained dark-gray biotite granite; and, in places, segregated areas of black mica (biotite) and scattered grains of magnetite occur.

A microscopic study of this rock (Museum No. 1,867) reveals a fine-grained, allotriomorphic-granular rock, without trace of the schistose structure shown in the thin section. It is composed of the closely interknitted mineral individuals, quartz, microperthitic orthoclase, microcline, plagioclase and biotite. The feldspar constituent is in excess of the quartz, and the large feldspar individuals contain rounded drop-like inclusions of quartz, and other feldspar species. The plagioclase gives small extinction-angles with the twinning lamellæ in basal sections, and approaches idiomorphic lath-shaped forms in crystal outline. The biotite is more or less altered to chlorite. Pressure metamorphism is shown in the peripheral shattering, wavy extinction, and lines of fracture, in the large grains of quartz and feldspar.

A chemical analysis made in the laboratory of the Geological Survey, from specimens of rock collected from this quarry, yielded the writer the following results:—

Silica, SiO_2	76.37
Alumina, Al_2O_3	13.31
Iron Sesqui-oxide, Fe_2O_3	1.21
Lime, CaO	1.13
Magnesia, MgO	0.10
Soda, Na_2O	4.02
Potash, K_2O	3.68
Ignition	0.20
Total	100.02
Specific Gravity	2.642
Weight of one cubic foot of stone expressed in pounds	165.12
Number of cubic feet of stone contained in one ton (2,000 pounds)	12.1
Percentage (ratio) of absorption	0.056

A comparison of the above chemical analysis with analyses of the Lithonia belt of contorted granite-gneiss, in DeKalb, Gwinnett and Rockdale counties, indicates, at once, the practical identity of the rocks.

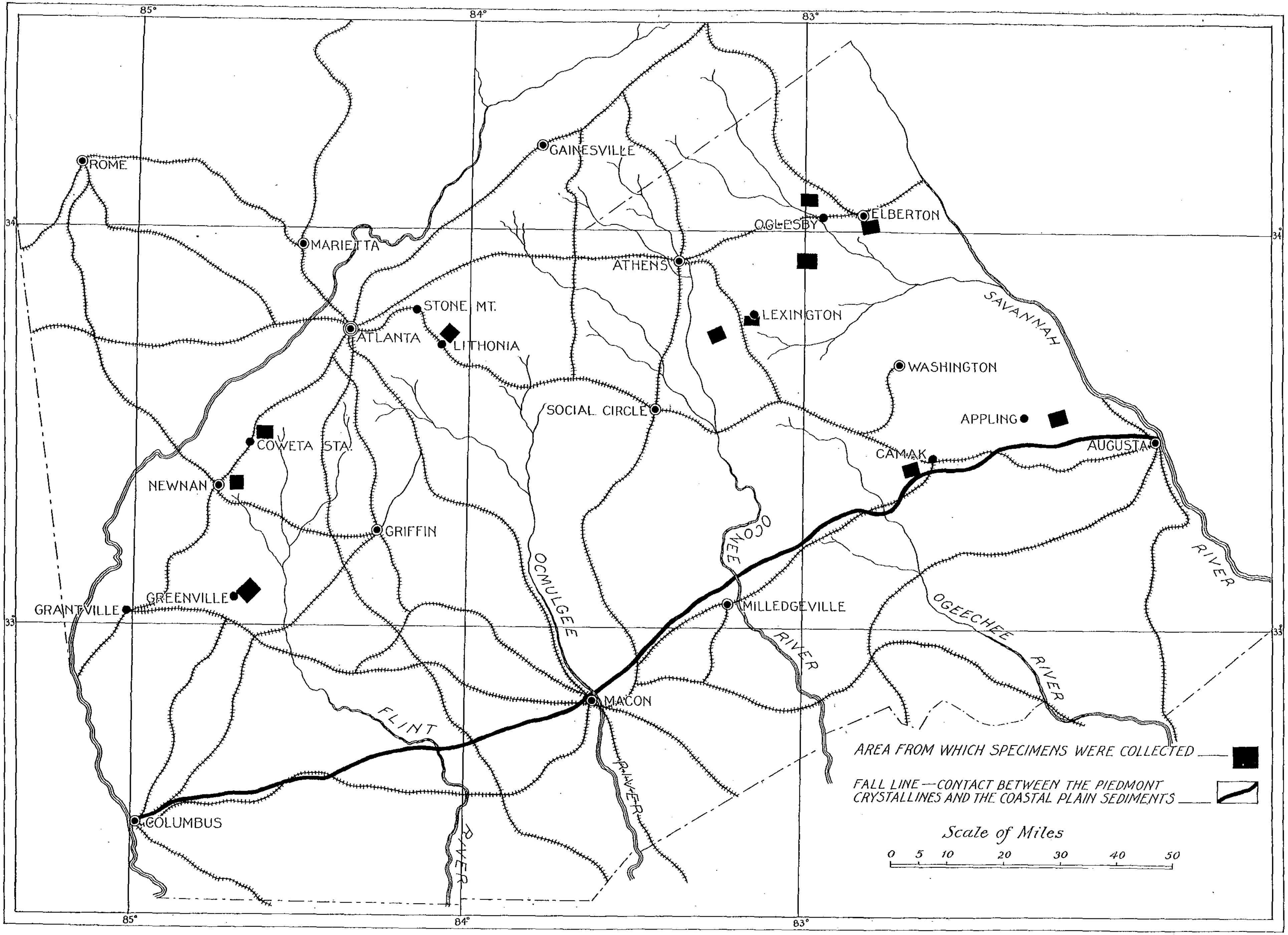
Outcrops of this rock occur at numerous points along the LaGrange-Greenville wagon-road, between Mrs. Hill's place and the Odessa quarry. Starting at the Odessa quarry and travelling in a slightly south-of-east course, outcrops of the contorted granite-gneiss may be seen on the following properties: Mrs. M. H. Dillard, J. M. Terrell, G. J. Martin, H. W. and A. F. Hill and Mrs. M. J. Hill, to and beyond Mrs. Hill's mill.

CEDAR ROCK.—This property is owned jointly by Messrs. J. L. Robertson and T. S. Wright, and is located four miles southeast from Greenville and two miles slightly south of east from Harris City. The outcrop covers at least one hundred acres, and is a flat doming mass of contorted granite-gneiss. Before reaching the main exposure, outcrops of the rock were noted on the south side of Kendall creek, where it is crossed by the public road, three miles southeast from Greenville. From this point to "Cedar-rock" proper, it is continuous. Near this point on the stream and on the northeast side of the wagon-road, a large body of mica-schist is exposed. The gneiss begins to outcrop again near Harris City, and is exposed at numerous places along the Greenville-Harris City wagon-road to Render's trestle, one mile south from Greenville.

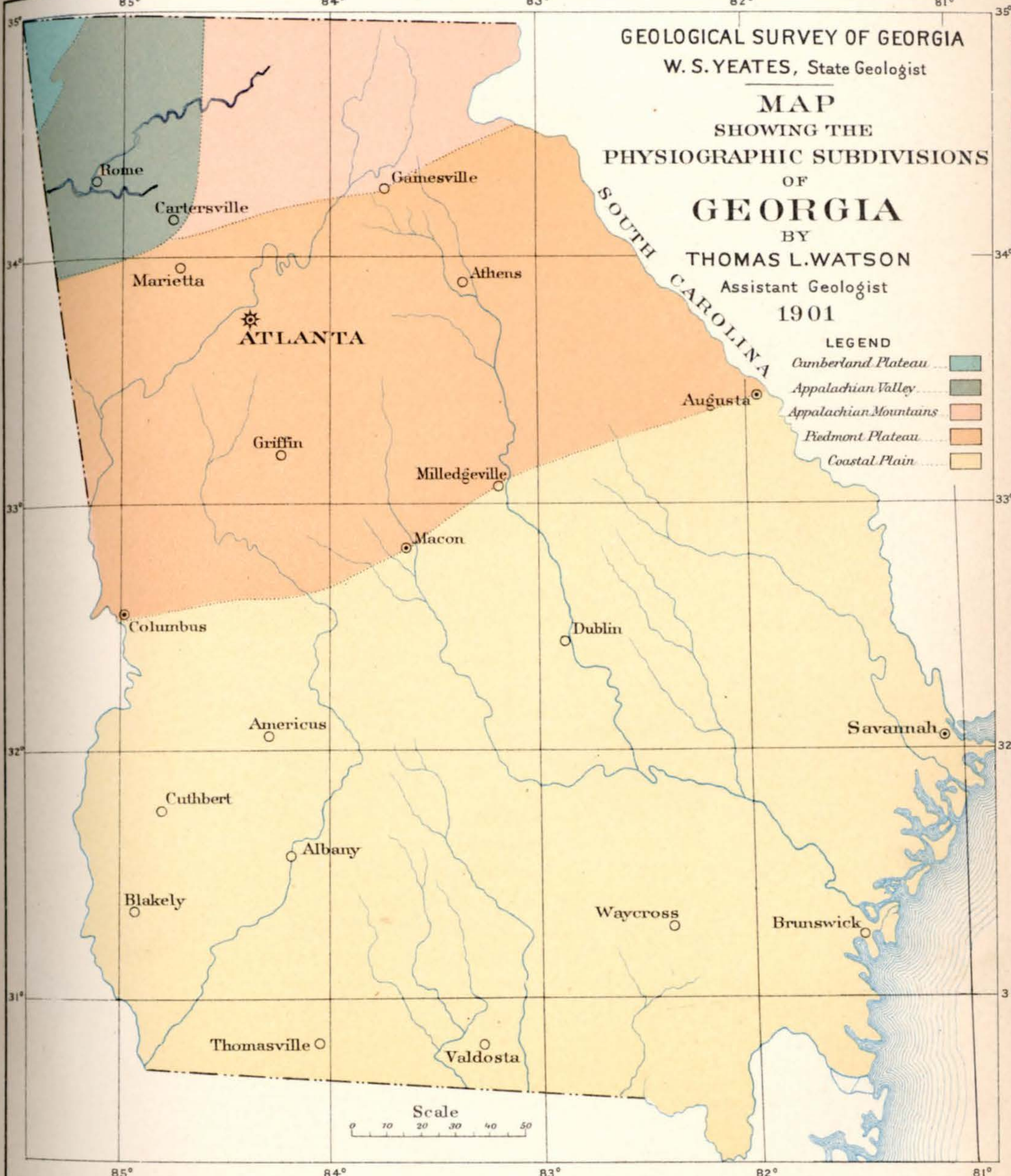
This is the same light-gray, contorted biotite granite-gneiss, as that described from the Odessa quarry, in which the component minerals, quartz, feldspar and biotite, are readily distinguished by the unaided eye. It can be easily worked ; is readily accessible to the railroad ; and is an excellent stone for street purposes. No work has been done on this property looking to its development.

THE H. W. HILL PROPERTY.—Approximately twelve acres of flat-surface and boulder outcrops of the same granite-gneiss, as that described above, occur one and a half miles southwest from Harris City, and about a quarter of a mile north from the Harris City-Stinson public road, in a field. One opening of slight dimensions has been made in the sheet outcrop, where the fresh rock could be seen to an advantage. Hand specimens of the rock from this locality and the Odessa quarry cannot be distinguished, except that the former is somewhat coarser in grain. A few scattered garnets are shown in the hand specimens of the Hill rock.

A thin section from a specimen of this rock (Museum No. 1,870), studied under the microscope, revealed a massive, allotriomorphic-granular rock, in which the schistose structure, so characteristic of the rock, is not shown. It is composed of the potash feldspars, orthoclase, with microperthitic structure, and microcline, and the soda-lime feldspar, oligoclase, with quartz and biotite. The individual crystalline grains are nearly equal in size. The microscope also indicates a slightly coarser-grained rock than the Odessa granite-gneiss. The feldspar constituent is in excess of the quartz. The usual microscopic inclusions abound in the larger grains of quartz and feldspar. The biotite also carries some included material, and is somewhat altered to chlorite and epidote. Mechanical strain is shown in the wavy extinction and lines of fracture, common to the large grains of quartz, and less frequently, the feldspar.



MAP SHOWING THE GRANITE LOCALITIES DESCRIBED


GEOLOGICAL SURVEY OF GEORGIA
W. S. YEATES, State Geologist
MAP
SHOWING THE
PHYSIOGRAPHIC SUBDIVISIONS
OF
GEORGIA
BY
THOMAS L. WATSON
Assistant Geologist
1901
LEGEND
Cumberland Plateau
Appalachian Valley
Appalachian Mountains
Piedmont Plateau
Coastal Plain
SOUTH CAROLINA
Rome
Cartersville
Gainesville
Marietta
Athens
ATLANTA
Augusta
Griffin
Milledgeville
Macon
Columbus
Dublin
Americus
Savannah
Cuthbert
Albany
Blakely
Waycross
Brunswick
Thomasville
Valdosta
Scale
0 10 20 30 40 50
85°
84°
83°
82°
81°
35°
34°
33°
32°
31°
A. HOEN & CO. BALTIMORE.

Other Exposures of Biotite Gneiss. — One mile east from Cedar Rock, along the public wagon-road, is an outcrop of contorted biotite gneiss. A quarter of a mile east from Render's dwelling, and on the same side of the road, is exposed about one acre of flat-surface outcrop of this rock. Numerous outcrops are to be seen along the wagon-road for a distance of a mile northeast from this place.

On Mr. Sanders Sims' place, three and a half miles west from Woodbury, on the Woodbury-Greenville wagon-road, is a flat-surface outcrop of approximately one acre of the gneiss.

On Mr. L. J. Render's place, four and a half miles west from Woodbury, on the south side of the above wagon-road, is a ledge outcrop of a coarse-grain, roughly contorted biotite gneiss, in which there are a dozen or more acres of the rock exposed.

A thin section of this rock (Museum No. 1,878), under the microscope, showed a medium coarse-grain rock, without a trace of schistose structure. It consists of interlocking quartz and the feldspars, microperthitic orthoclase, microcline and plagioclase, with large, stout intergrown plates of biotite. The quartz and feldspar individuals are allotriomorphic as to crystal outline. Disc-shaped intergrowths of quartz and feldspar, as micropegmatitic structure, are very common, and are frequently inclosed by some of the larger feldspathic grains with drop-like inclusions of quartz and feldspar. Inclusions are also common to some of the biotite shreds. Fracture planes and wavy extinction are characteristic of the quartz, and some of the feldspar individuals.

On Mr. R. D. Render's place, three miles east of Greenville, where Walnut creek is crossed by the Woodbury-Greenville wagon-road, are large boulder outcrops of gneiss. Outcrops of the same rock also occur on top of the hill along the same road, two miles east of Greenville.

Two miles northwest of Greenville, along a small stream, and directly on the west side of the Hogansville-Greenville wagon-road, is a one and a half- to two-acre outcrop of contorted biotite granite-gneiss on the Atkinson Brothers' place.

One and a quarter miles east from Harris City, on Mr. A. J. Barnes's place, are extensive outcrops of the same rock. The rock outcrops again two miles southwest of Harris City, on Mr. N. T. Wright's place.

A diabase dike, of considerable width, and traceable for several miles in a north and south direction, is exposed along the Harris City-Woodbury wagon-road, six miles slightly south of east from Greenville. This dike is found near, and has a course at right angles to, the east and west belt of gneissic rock. No contact has been found between the diabase and gneiss; but, while field evidence did not entirely reveal the actual cutting of the one rock by the other, it is certain, that, since the diabase dike has been traced in a north-south direction, for many miles to the north and south of the granite-gneiss belt, it cuts the gneiss, and is, therefore, more recent in origin. The numerous dikes of trap rock, found cutting the schists and gneisses of the Piedmont plain, are Mesozoic in age, and are the southern correlatives of the more numerous and extensive basic eruptives dissecting the middle and northern Atlantic seaboard.

A thin section of the dike rock made from a hand specimen collected from the above locality (Museum No. 1,871), indicated a typically normal, fine and compact-grain, dark blue-gray diabase. The rock is composed of colorless, slightly pleochroic augite, allotriomorphic-granular in outline; lath-shaped plagioclase; and idiomorphic magnetite crystals. It displays the characteristic ophitic structure.

Hornblende Gneiss

The T. B. Tigner Quarry.—An extensive area of a dark greenish black, distinctly laminated and fine-grain hornblende-gneiss outcrops along the Macon and Birmingham railroad to the east, about a half to three quarters of a mile from Mr. Tigner's dwelling-house. The rock has never been systematically quarried. The railroad has cut directly across a portion of the belt, where considerable stone has been taken out, and good sections of the rock are now exposed in the cuts. An eight-inch polished and hammer-dressed cube of this rock, on exhibition in the State Museum at the Capitol in Atlanta, shows, that the stone takes an excellent finish.

A thin section of the rock (Museum No. 1,875), studied under the microscope, revealed a fine-grain, banded or laminated hornblende-gneiss. The laminated structure is due to definite orientation of the ferro-magnesian silicate, hornblende, along parallel lines. The rock consists of hornblende, quartz, and potash and plagioclase feldspars, with epidote and some calcite, as secondary minerals. The mineral individuals are each allotriomorphic in outline. Hornblende is the principal mineral present. It makes up at least two-thirds of the rock-mass. It occurs as allotriomorphic plates, elongated in the direction of the prismatic cleavage. The marked cleavable grains are light yellowish-brown, parallel to the cleavage direction, and dark greenish-brown, at right angles to this direction. Extinction angles, measured with the cleavage planes, varied from 10° to 24°. More than half of the hornblende is partially altered to chlorite, and differs quite markedly from the remainder, in being massive and without definite cleavage-partings, green to blue-green in color, more feebly pleochroic, and weaker double refracting. The hornblende individuals are much larger in size, than any of the other minerals present.

This rock is quite similar in all respects to that described from Gwinnett county, occurring four miles southeast from Lawrenceville (Museum No. 1,938). It weathers to a deep red and highly ferruginous stiff, clayey mass.

COWETA COUNTY

Coweta county contains extensive areas of even-grain granites; their accompanying coarse-grain porphyritic granites; and granite-gneisses, of excellent quality, well adapted to general building and monumental purposes. These rocks are fairly well distributed over the county. A number of quarries have been opened at various places, and considerable stone has been quarried from some, which has been used almost exclusively for local purposes.

GRANITE

The granites are medium fine-grain, gray, biotite varieties, confined, for the most part, to the central, eastern and southern portions of the county.

The fine-grain, gray granites from this and the adjoining counties, Campbell and Meriwether, resemble quite closely in grain, texture and color, specimens of the Fitzwilliam granite of New Hampshire, included in the 10th Census collection of building stones, in the U. S. National Museum, Washington, D. C. More or less similarity is also observed between the Coweta-Campbell counties gray granites and specimens of biotite granite, included in the above collection from the Westham Granite Co., Manchester, Virginia, and the J. B. Mitchell Co.'s quarries in the Tuckahoe district, near Richmond, Virginia.

THE SAM HILL QUARRY. — This quarry is located three and a quarter miles slightly south of east from Newnan, the county-seat of Coweta, and an eighth of a mile from, and on the east side of, White Oak creek, near the edge of the gently sloping stream-valley. Itis owned by Mr. Samuel L. Hill, of Newnan. The granite outcrops more or less continuously over some twenty to thirty acres of land, extending from the above named stream back to the quarry. The quarry was opened about fifteen years ago, to obtain rock for the Central of Georgia railway, and was worked for a period of two years, averaging a large force of hands per day. In a direct course across the stream-valley, the quarry is not more than three quarters of a mile from the railway, between which points, a switch could be laid and operated at nominal cost. At the time of the writer's visit, the quarry-opening was nearly filled with water; but the apparent depth and width of the opening indicated, that a large amount of stone had been quarried. The quarry outcrop is only a few feet higher than the level of the stream, which will necessitate the use of machinery for removing the water, if quarrying is continued to any depth.

The rock is cut by a series of joint-planes trending south 35° east, and by a system of fine-grain dikes of biotite granite, of slight width, quite numerous in places, and approximately parallel with the jointing.

Megascopically, the rock is a medium fine-grain, dark blue-gray, biotite granite. In addition to the quartz, feldspar and biotite, scattered foils of muscovite are apparent to the unaided eye. The rock is quite uniform in color, grain and texture. Hand specimens of this and the Cole quarry granite described below, cannot be distinguished. The rock specimens from these localities resemble very closely the Oglesby blue granite in Elbert county. No free iron oxides were anywhere observed in the rock.

Microscopically, it is an allotriomorphic-granular rock in texture, composed of intricately interlocking grains of quartz and the feldspars, orthoclase, microcline and plagioclase, with folia of biotite. The quartz and feldspar individuals are entirely without crystal outline, and frequently occur intergrown in the form of micropegmatitic structure. The feldspars are usually characterized by a well marked banded or zonal structure. The orthoclase occasionally shows micropegmatitic intergrowths with a second feldspar, and is the predominating feldspar present. Plagioclase and microcline occur in approximately equal proportions. Biotite is present with its usual color and absorption, and is variously altered to chlorite and epidote. Scattered shreds of muscovite occur associated with the biotite. The quartz and feldspar individuals are further characterized by prismatic inclusions of accessory apatite and zircon. Mechanical deformation is manifested in the usual cataclastic phenomena.

The chemical composition of the rock is indicated in the following analysis made by the writer, in the laboratory of the Geological Survey: —

Silica, SiO_2	68.38
Alumina, Al_2O_3	17.79
Iron Sesqui-oxide, Fe_2O_3	1.21
Lime, CaO	2.85
Magnesia, MgO	0.72
Soda, Na_2O	4.36
Potash, K_2O	3.57
Ignition	0.78
Total	99.66

Other tests made yielded the following results: —

Specific Gravity	2 689
Weight of one cubic foot of stone expressed in pounds	168.06
Number of cubic feet of stone contained in one ton (2,000 pounds)	11.9

The rock weathers into a light-gray granitic sand, slightly stained or colored by iron oxide derived from the incipient decomposition of the biotite. It crumbles apparently into the incoherent sandy mass principally from hydration and temperature changes. In the advanced stage of decay, the derived product is a stiff, red clay—the result of the chemical decomposition of the feldspar and biotite.

An eight-inch polished and hammer-dressed cube, on exhibition in the State Museum at the Capitol in Atlanta, indicates the excellent finish the rock from the Hill quarry is capable of receiving. The stone is well suited to the various grades of work, for which granites are used. Abundant water-power is within close proximity to the granite outcrops.

The section traversed between Newnan and the Hill quarry to the southeast of Newnan, is composed of a finely laminated mica-schist, occasionally cut by diabase dikes, of varying widths. In no instance, was the diabase actually found cutting the granites, a fact due, most likely, to a lack of exposures, from the heavy mantle of residual decay; it is in evidence, however, that the granite has been intruded into the mica-schist. The rock sequence for this locality, then, is mica-schist, granite and diabase.

THE R. D. COLE QUARRY. — This quarry is located half-a-mile east of Newnan, in an open field, where a flat-surface outcrop, of less than an acre of the granite, is exposed. A number of smaller outcrops of the same rocks were observed, in places, in the same field. In the quarry, the decay is clearly visible to a depth of fifteen feet from the surface downward. This zone is very fittingly termed a "sheet zone", since the rock apparently lies in sheets of variable thickness, which are made more apparent from the weathering progressing along the invisible horizontal parting planes (rift) of the granite-mass. From this depth down, the rock appears perfectly massive, and is of a very superior quality.

The quarry was opened about twelve years ago, and has been worked subsequently, from time to time, when stones for local purposes were obtained. It has been used mostly as a building stone in the town of Newnan, from which cotton mills, ware-houses, and other buildings have been built, either in whole or in part. The quarry opening is a fairly large one, and has been worked to a depth of twenty-five to thirty feet, indicating a large amount of stone quarried.

Megascopically, the rock is a medium fine-grain, dark-gray, biotite granite, in which scattered plates of muscovite are visible. It resembles very closely the Oglesby blue granite in the hand specimen. Comparison of specimens of this with the Sam Hill, Carmichael and Greenville Granite Company's rock, can hardly be distinguished. A slight variation in color and grain of the rock from the above localities, occurs, as would be expected, for localities so widely separated; and yet a glance is sufficient to establish the practical identity of the rock over the region.

The rock is cut by two well defined sets of joint-planes having east-west and north-south directions, and about equal development.

In addition to the joints, numerous veins, composed of coarsely crystallized quartz and feldspar, and some biotite, with occasional muscovite, intersect the rock in all directions. A majority of the veins seemingly conform, however, with the north-south set of joints.

Microscopically, this is a fine, even-grain biotite granite, composed of interlocking crystals of quartz and feldspar, with biotite and some muscovite. The feldspar constituent consists of orthoclase with some microperthitic intergrowths, microcline and plagioclase, in about equal proportions. Marked zonal and twinning structures are common to the feldspars. The quartz and feldspars are allotriomorphic in outline. Biotite occurs with the usual color and absorption, and is greatly altered to epidote, with and without crystal outline, which exhibits faint pleochroism and high double-refraction. The large partially idiomorphic plates of epidote display perfect cleavage, parallel to (001) and a very much less distinct parting parallel to (100) in sections parallel to (010). The change from biotite to epidote is well marked, and some of the larger cleavable grains contain fragmentary centres of the fresh and partially altered biotite. Prismatic inclusions of apatite and zircon, and some chlorite and muscovite as secondary products, are present in the thin sections.

Chemical analyses of specimens of the fresh and partially decomposed rock yielded the writer the following results, in the laboratory of the Geological Survey :—

	I	II	III
Silica, SiO_2	69.08	61.18	56.99
Alumina, Al_2O_3	17.67	22.80	26.02
Iron Sesqui-oxide, Fe_2O_3	1.41	1.74	1.91
Lime, CaO	3.27	3.06	0.75
Magnesia, MgO	0.64	0.34	0.17
Soda, Na_2O	4.56	7.94[1]	1.91
Potash, K_2O	3.29		2.40
Ignition	0.56	2.94	9.76
Total	100 48	100.00	99.91

I Analysis of fresh granite.
II Analysis of partially decomposed granite taken ten feet below the surface.
III Analysis of decomposed granite taken five feet below the surface.

Re-calculating the analyses in columns I and III on the basis of 100, and assuming the alumina to remain constant, which serves as a basis for estimating the amounts lost and saved per each constituent present, a total percentage loss for the entire rock of 38.48 per cent. was obtained in passing from the fresh rock to the stage represented in the decay under column III.

On comparing the analysis of the Cole with the Hill granite, a very close agreement throughout will be observed, except in the percentage of lime, which is somewhat higher in the case of the Cole granite, because of the increased amount of epidote present.

Other tests made were :—

Specific Gravity at 19°C.	2.700
Weight of one cubic foot of stone expressed in pounds	168.75
Number of cubic feet of stone contained in one ton (2,000 pounds)	11.8

The granite from this quarry is well adapted to general building and monumental work.

A thin section, made from a partially weathered specimen of the granite (Museum No. 1,895), indicated some decay in the biotite and feldspars, resulting in the liberation of iron oxide from the former, which discolors the section to some degree, and a partial kaolinization of the feldspars. A somewhat larger proportion of biotite is present in this section, than in that made from the fresh rock (Museum No. 1,887).

The final product of weathering is a highly ferruginous, stiff red clay. The manner and process of weathering of the granite from the Cole quarry is detailed in Chapter V, Part 2, on Weathering, in this report.

Between 150 and 200 yards west of the Cole quarry, a second

[1] Calculated by difference.

opening has recently been made in a heavy banded gneiss, and some of the rock has been quarried for local purposes in Newnan. The mineral bands of this rock are strongly contrasted in color. The very dark layers are composed principally of highly lustrous plates of black biotite; while the white bands are made up of quartz and feldspar, with occasional small crystals of red garnet.

THE OVERBY QUARRY. — Approximately one and a half acres of exposed rock, as sheet or nearly flat-surface outcrops, occur in and along a tiny stream 100 yards from the Overby dwelling-house, and ten miles slightly north of east from Newnan. It is further located nine miles northeast from the Sam Hill quarry, with outcrops of the same rock traceable between the two.

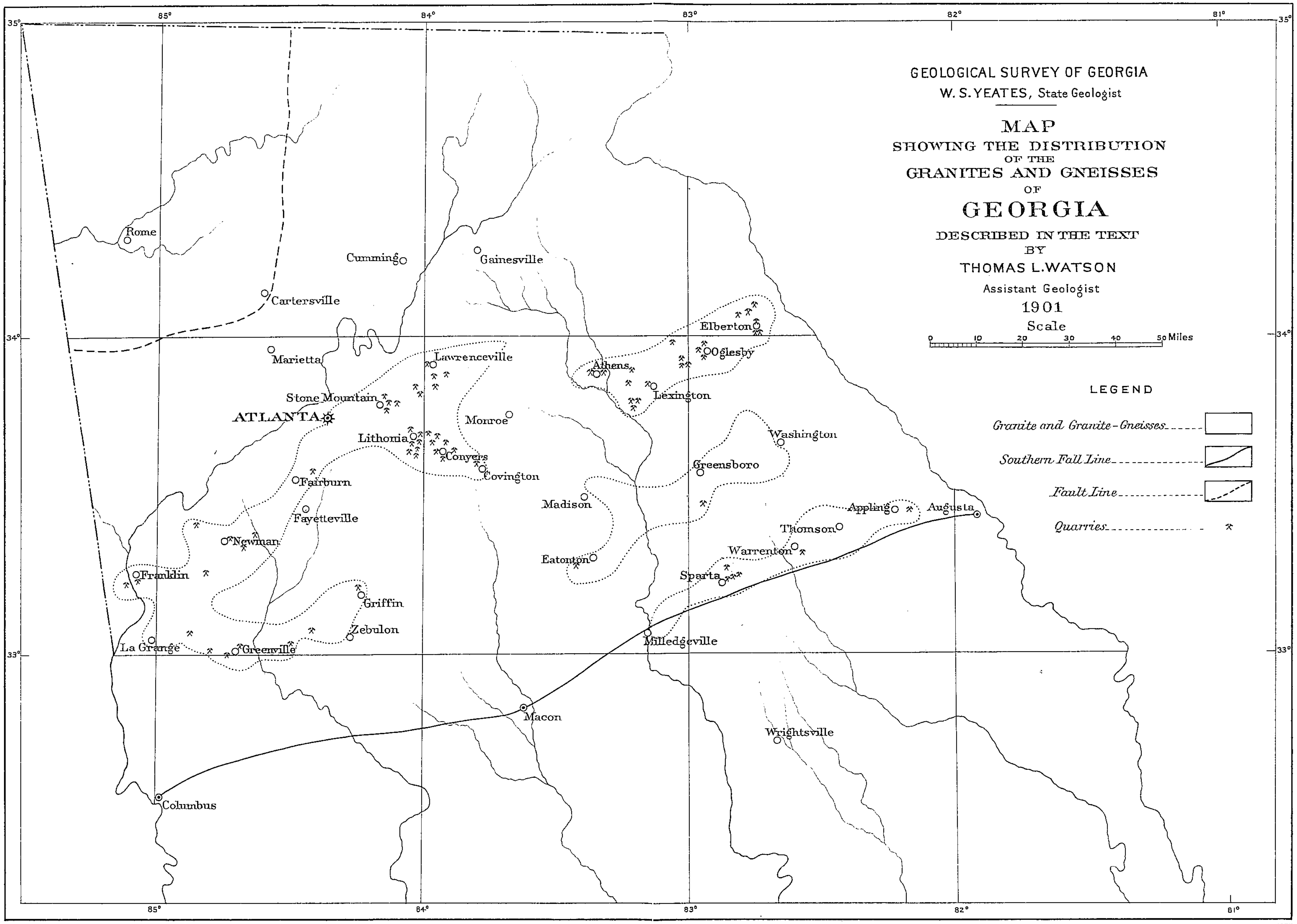
The property was sold by the owner, Mr. M. H. Overby, in January, 1899, to Mr. J. H. Wynn. One raise has been made, extending over most of the outcrop, and the rock quarried was used for bases to monuments; sills to windows and doors in buildings; and retaining walls in cemeteries.

Macroscopically, the rock is a medium uniform-grain biotite granite, of medium gray color. It is a shade coarser in grain, and lighter in color, than the similar rock described above, from the Cole and Hill quarries; and it is difficult to distinguish in the hand specimen from the Carmichael granite in Campbell county, and that of the Greenville Granite Company in Meriwether county. The component minerals, quartz, feldspar and biotite, are readily identified by the unaided eye. Microscopically, the rock is the same as that described from the above quarries, with which it is compared.

A chemical analysis of the granite from this quarry yielded the writer, in the laboratory of the Geological Survey, the following results: —

Silica, SiO_2	68.81
Alumina, Al_2O_3	17.67
Iron Sesqui-oxide, Fe_2O_3	1.13
Lime, CaO	2.17
Magnesia, MgO	0.50
Soda, Na_2O	4.97
Potash, K_2O	3.90
Ignition	0.56
Total	99 71

Outcrops of apparently the same granite were observed at two points, three and a half and five miles, respectively, west from the Overby quarry, along the Newnan public wagon-road. Outcrops of this rock are more or less continuous from the quarry along the same road to a point five miles east of Newnan.


GEOLOGICAL SURVEY OF GEORGIA
W. S. YEATES, State Geologist
MAP
SHOWING THE DISTRIBUTION
OF THE
GRANITES AND GNEISSES
OF
GEORGIA
DESCRIBED IN THE TEXT
BY
THOMAS L. WATSON
Assistant Geologist
1901
Scale
0 10 20 30 40 50 Miles
LEGEND
Granite and Granite-Gneisses
Southern Fall Line
Fault Line
Quarries
35°
34°
33°
85°
84°
83°
82°
81°
Rome
Cartersville
Cumming
Gainesville
Marietta
Lawrenceville
Stone Mountain
ATLANTA
Monroe
Lithonia
Conyers
Covington
Fairburn
Fayetteville
Newnan
Franklin
Griffin
Zebulon
La Grange
Greenville
Athens
Elberton
Oglesby
Lexington
Washington
Greensboro
Madison
Eatonton
Appling
Augusta
Thomson
Warrenton
Sparta
Milledgeville
Macon
Wrightsville
Columbus
A. HOEN & CO. BALTIMORE

THE J. H. NEELY PLACE. — A slight opening has been made in a boulder outcrop, occurring near a small stream, half-a-mile southwest from Sharpsburg, and a quarter of a mile from the depot on the Central of Georgia railway. The outcrop is very small at this point.

Megascopically, the rock is a very fine-grain, medium-gray biotite granite, closely resembling the granite from the Cole quarry. Muscovite is apparent in the hand specimen. A few veins were observed cutting the rock in the quarry.

A thin section of the rock (Museum Cat. No. 1,884), examined under the microscope, revealed a fine-grain, allotriomorphic-granular granite, composed of interlocking quartz, orthoclase and some plagioclase, with small folia of biotite and muscovite shreds. No microcline was present in the slide. Micropegmatitic or granophyric intergrowths of quartz and feldspar were not observed in thin sections of this rock. The feldspar and biotite were somewhat altered to chlorite, epidote, muscovite, kaolin and some calcite.

Outcrops of granite were noted at the following points along the Sharpsburg-Newnan public road: At the crossing of Bailey's creek by the Sharpsburg-Newnan wagon-road, seven miles from Newnan; at the crossing of the same road by Goodwin creek, six miles from Newnan; and between the two streams. The prevailing country-rock between Newnan and Sharpsburg is mica-schist.

MRS. J. D. MORELAND'S PROPERTY. — Half-a-mile west from Grantville, in the southern part of Coweta county, occur outcrops of an irregularly banded grano-diorite gneiss. The rock is exposed on both sides of the wagon-road, near a small stream at the foot of a hill. Some of the rock has been quarried from the outcrop on the south side of the road, and used for foundations and rough work in Grantville.

Hand specimens indicate a medium coarse-grain, distinctly black-and-white-speckled rock. The biotite is distributed through the rock in small areas of grouped plates, of brilliant lustre and black color, with which always occurs an abundance of lemon-yellow epidote. The rock is irregularly banded, and contains some segregations. Neither of these structures is apparent in the hand specimen. Large crystals of magnetite are scattered through the rock-mass.

A thin section (Museum No. 1,889), under the microscope, indicated a medium-grain, hypidiomorphic-granular rock in texture, composed of the following minerals, named in the order of abundance: Quartz, plagioclase and orthoclase, with biotite and several plates of cleavable hornblende with strong absorption. Epidote in large quantity, chlorite, some calcite, and muscovite are present as derived or secondary minerals. Plagioclase is the predominant feldspar present. It shows strong idiomorphic tendency in outline. No microcline occurs. Biotite, as large plates with deep color, strong absorption, and marked basal cleavage, is very abundant in grouped or aggregated areas. It is greatly altered to faintly pleochroic and strongly double-refracting epidote, with and without crystal outline. The idiomorphic crystals of epidote exhibit marked cleavage parallel to (001), and a less well defined parting parallel to (100), in sections parallel to (010). The occurrence of epidote in this rock, as marked cleavable crystals, is very similar to that in the granite from the Cole quarry; but it is much more abundant in the Grantville than in the Cole granite. The alteration from biotite is shown in numerous cores of partially decomposed biotite in the larger epidote crystals.

The chemical composition of the Grantville rock is shown in the following analysis made by the writer in the laboratory of the Geological Survey: —

Silica, SiO_2	66.92
Alumina, Al_2O_3	18.19
Iron Sesqui-oxide, Fe_2O_3	3 05
Lime, CaO	4.95
Magnesia, MgO	1.26
Soda, Na_2O	3.83
Potash, K_2O	2.02
Ignition	0.46
Total	100.68

The increase in the percentage of soda over that of the potash, added to the lime content, indicates the preponderance of soda-lime, over potash, feldspar. This fact is corroborated by the microscope. The high percentage of lime is attributed to the increased amount of epidote present. The increased proportion of biotite in the rock is shown in the rather high percentages of iron and magnesia.

The outcrops of the rock indicate crumbling from temperature changes and hydration, into a coarse-grain, gray granitic sand, in which no chemical change is apparent further than feldspathic kaolinization. A cut in the wagon-road, fifty paces from an outcrop, reveals, however, a more advanced stage in the weathering of the rock. At this point, chemical forces have been very active, and the rock is reduced to a highly ferruginous, deep red and stiff, clayey residual product.

A second outcrop occurs one and a quarter miles slightly south of west from Grantville on Mr. T. M. Zellars' place. The rock has been worked, to some extent, and a fair quantity of stone taken out.

Granite outcrops are first seen on the south side of Camp creek, three miles north from Grantville, along the Newnan-Grantville public road, and are more or less continuous into Grantville.

THE LYNDON HILL PROPERTY. — One mile southeast from the court-house in Newnan, a small outcrop of fine-grain, very light-colored, nearly mica-free granite occurs. Rock was being quarried, at the time of the writer's visit, for foundation-stone, to be used in a church building. Stone was quarried some years ago from a near-by exposure of the same rock.

A thin section of the rock (Museum No. 1,903), under the microscope, revealed a medium-grain granite, composed principally of quartz and feldspar with occasional small shreds of biotite and muscovite. Orthoclase is present in great excess over the microcline and plagioclase feldspars, and the rock may be said to be composed principally of quartz and orthoclase. Numerous inclusions of apatite and zircon, and rounded grains of quartz and feldspar, in the form of drop-like inclusions, occur in the larger individual crystals. A few intergrowths of quartz and feldspar, as micropegmatitic structure, are present. This property is owned by Mr. A. J. Lyndon, Athens, Ga.

PORPHYRITIC GRANITE

The porphyritic granite area is limited to the northeast section of Coweta county, and is the equivalent of the same rock occurring to the north and east, in Campbell and Fayette counties, respectively.

As indicated by specimens in the 10th Census collection of building stones, in the U. S. National Museum, Washington, D. C., coarse-grain porphyritic biotite granite, resembling, in every respect, that of the granite area of Coweta, Campbell and Fayette counties in Georgia, occurs near Rockingham, in Richmond county, North Carolina, and Mt. Monroe, Iredell county, in the same State. A description of the rocks from the Georgia area would answer equally well for the similar ones in North Carolina.

THE MCCOLLUM QUARRY. — On the property of Mr. J. R. McCollum, of Newnan, Georgia, occur several outcrops of a coarse-grain porphyritic granite, nine miles northeast from Newnan, on the Atlanta and West Point railroad, near Coweta station. Approximately one acre of the exposed granite occurs three eighths of a mile slightly north of east from the station, on a gently sloping hill. Outcrops are seen along several small streams, from two to two and a half miles south of east from the above field-exposure, the principal one of which includes one and a half acres, located about one hundred yards from the east fork of Shoal creek, and two miles east from Coweta station. A good section of the partially fresh and decayed rock is shown in a cut of the Atlanta and West Point railroad, a short distance north of the station. The exposures on Mr. McCollum's place indicate a belt approximately three miles long, in a northwest-southeast course, and as much as three quarters to one mile wide, in places. Several handsome blocks of the stone have been collected for exhibition purposes. One of these is on exhibition in the State Museum at the Capitol in Atlanta. The excellent finish, the rock is capable of receiving, is well shown in the polished and hammer-dressed faces of the eight-inch cube in the State Museum.

Megascopically, the rock is a very coarse-grain porphyritic biotite granite, of medium-gray color. The porphyritic minerals are the potash feldspars, orthoclase and microcline.

A thin section (Museum No. 1,901), made of one of the phenocrysts, showed the characteristic microcline structure and inclusions of all the groundmass minerals under the microscope.

Chemical analyses of specimens of the fresh and decomposed phenocrysts from the rock gave the writer the following results: —

	Fresh Feldspar	Partially Decomposed Feldspar
Silica, SiO_2	64.40	59.70
Alumina, Al_2O_3	18.97	21.73
Iron Sesqui-oxide, Fe_2O_3	0.37	0.60
Lime, CaO	0.59	0.04
Magnesia, MgO	trace	trace
Soda, Na_2O	3.60	2.09
Potash, K_2O	11.40	13.80
Ignition	0.19	3.00
Total	99.52	100.96

Specific Gravity . . . . 2.60 (Thoulet's Solution)

The phenocrysts measure two inches and more in length, in extreme cases; and are prevailingly irregular in outline; but they are frequently tabular, parallel to the clinopinacoid (010), and twinned according to the Carlsbad law. Cleavages parallel to the base (001) and clinopinacoid (010) are generally well developed.

Microscopically, the rock is very coarse-grain, and porphyritic in texture, and is composed of quartz and the potash feldspars, and plagioclase with biotite. The quartz anhedra are crossed by lines of fracture, and, in addition, display wavy extinction. The plagioclase is lath-shaped in outline, and exhibits broad twinning-bars with small extinction angles, in basal sections, indicating a feldspar near oligoclase. The orthoclase shows good cleavage and is intergrown with both plagioclase, probably albite, and quartz in the form of microperthitic and micropegmatitic intergrowths. Biotite is present in large grouped plates, with deep color, strong absorption, good basal cleavage, and containing numerous inclusions. Some epidote, chlorite and muscovite occur as secondary minerals. The feldspars contain an unusually large proportion of fairly large prismatic inclusions of apatite.

Chemical analyses of the fresh and weathered rock from this locality yielded the writer the following results : —

	I	II	III
Silica, SiO_2	63.65	60.28	53.58
Alumina, Al_2O_3	20.46	22.45	26.27
Iron Sesqui-oxide, Fe_2O_3	2.20	2.53	3.07
Lime, CaO	3.38	0.83	0.17
Magnesia, MgO	1.50	0.58	1.44
Soda, Na_2O	4.75	7.84[1]	1.88
Potash, K_2O	4.58		3.85
Ignition	0.42	5.49	9.02
Total	100.94	100.00	99.28

I Analysis of the fresh porphyritic granite.
II Analysis of partially decomposed porphyritic granite.
III Analysis of partially decomposed porphyritic granite collected in the Atlanta and West Point railroad cut.

Re-calculating the analyses in columns I and III to a basis of 100, and estimating the percentage loss for the entire rock, in passing from the fresh rock to the stage in decay represented under column III, we find a total loss of 35.07 per cent.

On comparing the analysis in column I of the above porphyritic granite with that of its correlative from Fayette county,[2] the indentity of the rock from these localities becomes apparent, chemically.

An excellent section exposing the residual decay of the porphyritic granite to a depth of 20 to 30 feet, may be seen in the Atlanta and West Point railroad cut, a few hundred yards north of Coweta station. The color of the residual product at this point, is prevailingly light-gray, stained a dull yellow from the decomposition of the mica folia, and mottled with the large, white, kaolinized phenocrysts of feldspar. Portions of fairly fresh, hard and firm rock are seen in places through the cut. The granite is readily traceable for five miles along the railroad, north of the McCollum place, into Palmetto. On the east side of the road, may be seen gullies 15 to 20 feet in depth, trenched in the red residual clay derived from the porphyritic granite. The residual soil from the decay of the granite is prevailingly red in color, in this locality.

Beginning at Coweta station and extending 250 to 300 yards

[1] Calculated by difference. [2] See page 103.

north along the railroad, is a large body of finely laminated mica-schist, which, at the above limit from the station, comes in direct contact with the granite. The contact between the decayed products of the two rocks in the cut is very sharp and easily traced. To the north of this point, the schist is seen to overlie the granite at many places.

A number of exposures of the contact between the weathered products of the granite and schist may be seen to good advantage at different points along the wagon-road between Coweta station and Palmetto. The relationship between the schist and granite is therefore apparent. The schist forms the country-rock, and is older than the porphyritic granite. The younger rock was intruded into the schist, and subsequently, exposed by means of erosion and removal of the overlying mass of schist, and, it may be, other rocks, of which no record has been left.

Granite-Gneiss

As the name implies, the type of granitic rock here designated is characterized by a distinct schistose or laminated structure. The mica folia have been orientated along definite parallel lines or planes, in the direction of their longer diameters, imparting a regular and thin banded structure to the rock. Extensive areas of this rock occur in the northwest section of Coweta county, bordering the Chattahoochee river, and beyond, in Heard and Carroll counties, on the west and north, respectively. The rock outcrops as flat surfaces and low, dome-shaped masses, forming the prominent hills and ridges in this section. The surface configuration is much less subdued in this, than in other portions of the county, and the topography is more characteristic of "the hill-and-valley type" than elsewhere observed. The most extensive outcrop is that known as Flat-rock, which derives its name from the character of the rock-exposure at the surface. It is located in the *4th district*, eleven miles northwest from Newnan. The rock begins to outcrop at Mr. B. H. Pearson's house, one mile south of the river, and is continuous across the river into Carroll and Heard counties.

A few rocks have been quarried, from time to time, in various places over the belt, for local purposes, such as chimneys, foundations etc.; but no regular or systematic quarrying has been atattempted. The main body of the rock exposed in Coweta county is six miles from Sargent, the nearest railroad point.

Macroscopically, the rock is a light-gray, thinly laminated, biotite granite-gneiss, in which quartz, feldspar and biotite are readily identified by the unaided eye. It somewhat resembles in structure typical "augen-gneiss." Veins, an inch and more in width, cut the rock-mass in places.

A thin section from a specimen of the rock (Museum No. 1,886), showed, under the microscope, a medium fine-grain allotriomorphic-granular rock, without a trace of the schistose structure apparent. The rock consists of feldspar, quartz and biotite, with a good proportion of muscovite. The feldspar constituent consists of approximately equal amounts of orthoclase with albitic intergrowths (microperthitic structure) and microcline, with some lath-shaped crystals of plagioclase. This fact is confirmed by the analysis, below. The arrangement of mineral inclusions along definite lines is quite characteristic of the plagioclases. The microcline structure is increased in the thin section of this rock, and may possibly be derived in part from orthoclase as a result of pressure. The effects of pressure metamorphism are manifested in the peripheral shattering of the larger quartz and feldspar individuals. Inclusions are common to the quartz, feldspar and biotite. Epidote, garnet, muscovite and chlorite are present in microscopic proportions as secondary minerals.

The chemical composition of the rock is shown in the following analysis, made by the writer in the Geological Survey laboratory: —

Silica, SiO_2	73.95
Alumina, Al_2O_3	14.23
Iron Sesqui-oxide, Fe_2O_3	1.29
Lime, CaO	1.07
Magnesia, MgO	0.23
Soda, Na_2O	4.61
Potash, K_2O	5.29
Ignition	0.25
Total	100.92

A comparison of this analysis with that of the Flat-shoals rock in Meriwether county, and Flat-rock in Heard county, practically establishes their chemical identity. While the rocks from the above localities vary more or less in appearance, they are characterized by the same structure, and mineral and chemical composition.

Two 8-inch cubes, of this rock from the Bevins quarry, just across the line in Heard county, polished and hammer-dressed, in the State Museum at the Capitol in Atlanta, indicate, that it is capable of taking a good finish. The polished face of one of the Museum specimens is across the foliation or schistosity; and the feldspars and quartz present somewhat drawn-out or slightly lens-shaped areas between the biotite layers, in the direction of the lamination, with a striking "augen" appearance.

Seven miles somewhat north of west from Newnan, on the opposite side of the stream from Mr. Summers' house, is an extensive outcrop of a medium fine-textured, laminated, dark-gray biotite gneiss, crossing the highway. The gneiss at this point apparently contains more biotite, than the main body of the Flat-rock. The prevailing country-rock, traversed along the highway from Newnan to Flat-rock, is mica-schist, cut in places by dikes of a basic rock, *diabase*.

PIKE COUNTY

Pike county lies immediately south of Spalding county and east of Meriwether, with extensive areas of excellent granitic rock found within the borders of each. The Pike county rock consists of porphyritic granites and biotite gneisses. While no quarrying has been done in this county, large areas of the two varieties of rock mentioned exist, which are easily accessible and can be readily worked.

Beginning in the western limits of the town of Zebulon, the county-seat of Pike, along the main east-and-west street, are ledge and boulder outcrops of a coarse-grain biotite gneiss, continuous along the east side of a deep ravine, half-a-mile west of the town. Some of the surface rock from this outcrop was quarried and used as lintels and steps in the old court-house, built in 1848. Most of this material has been used again, for the same purpose in the new court-house recently completed. The rock used was unfortunately surface material and partially weathered, presenting somewhat of a dead and unattractive appearance, which by no means does the stone full justice. The feldspars are consequently rendered dull and opaque from kaolinization.

Microscopically, the rock is a semi-porphyritic foliated granite, composed of interlocking aggregates of quartz; the potash feldspars, microperthitic orthoclase and microcline; soda-lime feldspar, probably oligoclase; and biotite. The potash feldspars are the porphyritically developed minerals, and are usually surrounded by a crushed zone of a fine-grain mozaic of quartz and feldspar. A schistose structure has been induced by metamorphism, causing a re-arrangement of the biotite folia along somewhat definite parallel lines. It is further shown in the crushed zones, the numerous fracture planes, and the wavy extinction in the quartz and feldspar grains. The feldspars are variously altered by kaolinization, manifested in the opaque and cloudy condition of

Fig. 1

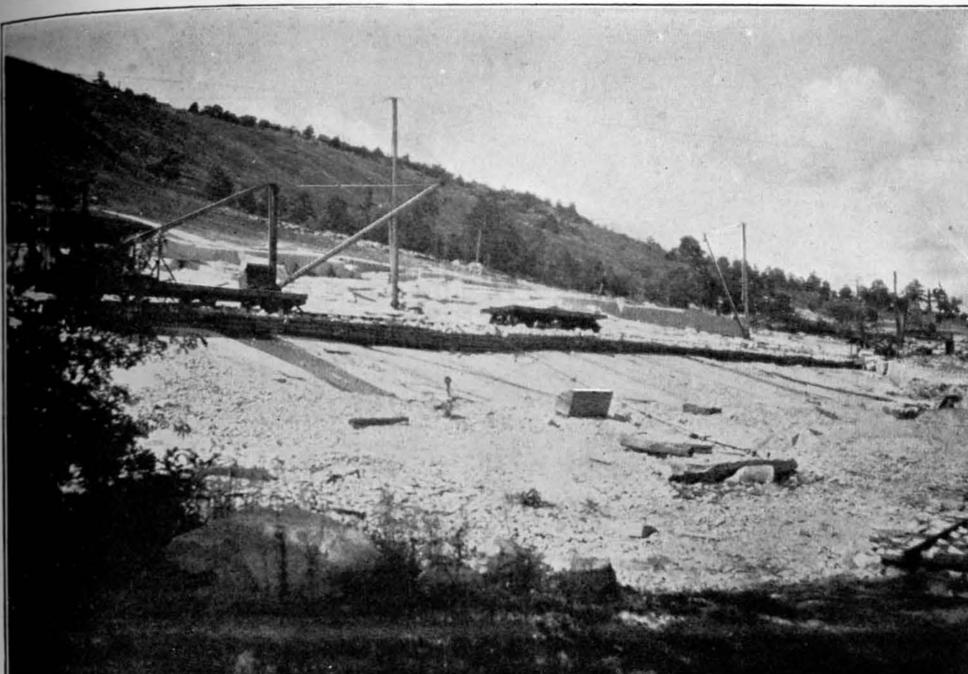
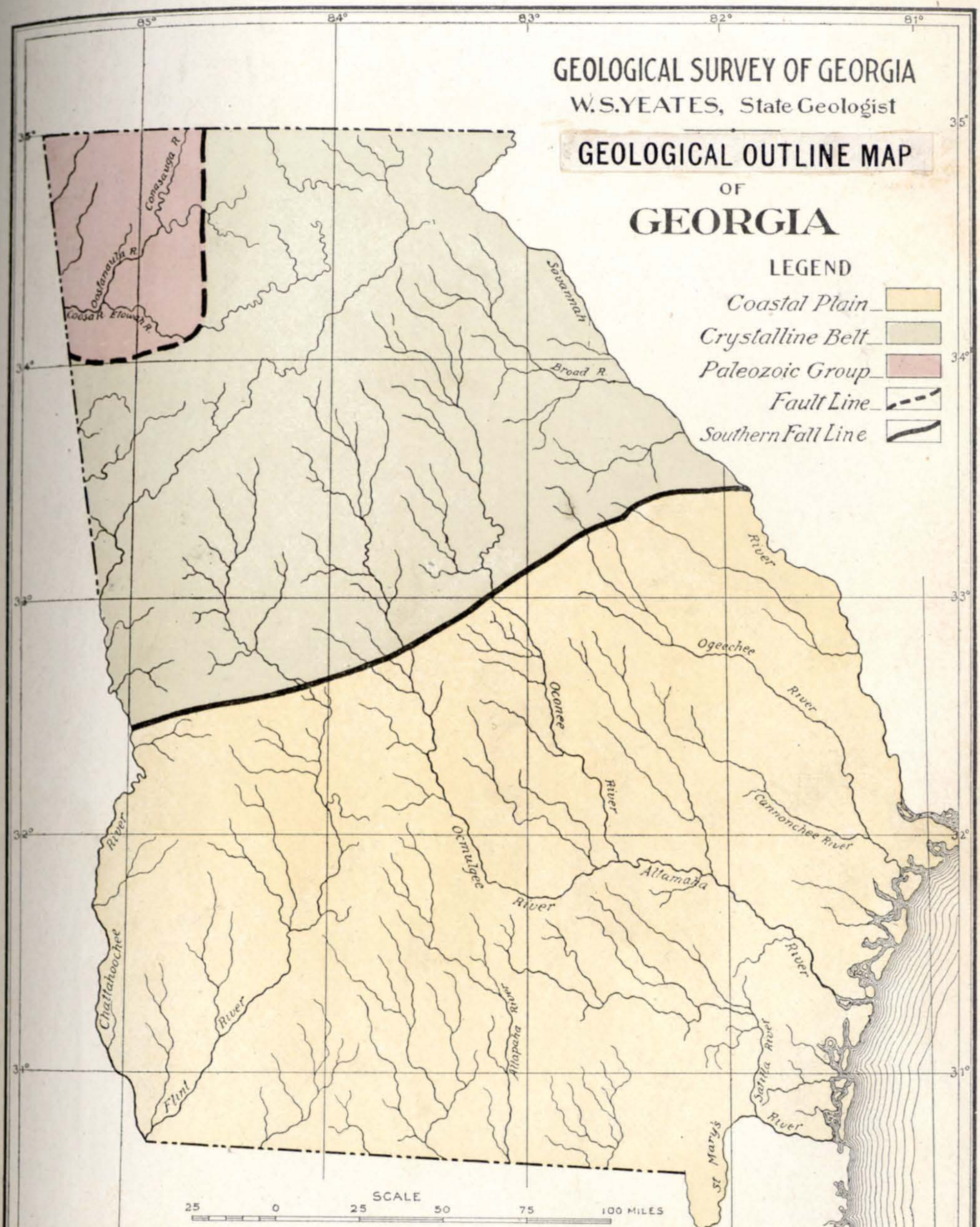


Fig. 2

STONE MOUNTAIN QUARRIES.

Fig. 1. A Quarry on the South Side of the Mountain.

Fig. 2. The Hanye Quarry, on the Northwest Side of the Mountain.


GEOLOGICAL SURVEY OF GEORGIA
W. S. YEATES, State Geologist
GEOLOGICAL OUTLINE MAP
OF
GEORGIA
LEGEND
Coastal Plain
Crystalline Belt
Paleozoic Group
Fault Line
Southern Fall Line
85°
84°
83°
82°
81°
35°
34°
33°
32°
31°
Conasauga R.
Oostanaula R.
Coosa R.
Etowah R.
Savannah
Broad R.
River
Ogeechee
River
Oconee
River
Canoochee River
Altamaha
River
Ocmulgee
River
Allapaha River
Satilla River
River
St. Mary's
Chattahoochee
River
Flint
River
SCALE
25
0
25
50
75
100 MILES

their surfaces. The biotite is present usually as grouped aggregates of intergrown foils arranged along approximately parallel lines; and also, as scattered single folia. In parallel polarized light, it is deep-reddish to light-brown in color, with strong absorption and good cleavage. Single small shreds of muscovite are occasionally intergrown with the biotite. Alteration of the biotite into chlorite, some epidote and ferric oxide occur.

Five miles northwest from Zebulon and one mile from the Georgia Midland branch of the Southern railway, is a flat-surface outcrop, of approximately one acre, of a coarse-grained, dark-colored biotite gneiss, along the Hollinsville-Zebulon wagon-road. The rock contains a large proportion of black mica; and the component minerals, feldspar, quartz and biotite, are easily identified by the unaided eye. Outcrops of gneiss, carrying an abundance of black biotite folia, and suitable for rough work, occur in various places in the county—principally at the following points: Quit post-office, in an open field on the west side of the Griffin-Zebulon turnpike, and at Moore's mill, in a stream-bed, where the stream crosses the above wagon-road, a quarter of a mile south of the Spalding county-line, and eight miles north of Zebulon.

THE FLAT ROCK PORPHYRITIC GRANITE AREA.[1]—This large body of rock is located nine miles slightly north of west from Zebulon, and four miles west from Concord and Jolly, stations on the Georgia Midland railroad. At the lowest estimate, the area contains 50 acres of continuous flat-surface outcrop. Owing to the manner and extent of the outcrop and to the numerous clusters of Cedar trees generally found growing over the rock-surface, it is known as "Flat-rock" and "Cedar-rock," respectively. The rock has never been worked, except now and then a surface "raise" is made, and some stone is obtained for chimneys and foundations for the dwelling-houses in the immediate neighborhood. The stone can be easily quarried, and is of excellent quality.

In the hand specimen, the rock is medium-grained, varying from even-granular to distinctively porphyritic in texture, and assuming more or less of a gneissoid or banded structure, in places. The component minerals, quartz, feldspar, biotite and some muscovite, are quite readily distinguished by the unaided eye. Biotite is very abundant, and is uniformly distributed, imparting a medium dark-gray color to the rock. In the porphyritic facies of the rock-mass, the white phenocrysts are of the potash feldspars, orthoclase and

[1] Also known as Cedar Rock.

microcline, from 10 to 30 millimeters long, and from 5 to 10 millimeters broad. They are tabular, parallel to the clinopinacoid (010), with good cleavage development parallel to the base (001) and the clinopinacoid (010), and are usually twinned according to the Carlsbad law. Enclosures of biotite folia, of the same dimensions as those occurring in the groundmass, are very abundant in the feldspar phenocrysts.

Microscopically, the rock consists of porphyritically developed orthoclase embedded in a coarse-grained groundmass of interlocking quartz, microperthitic orthoclase, microcline and some lime-soda feldspar (plagioclase), with biotite foils intimately associated with occasional muscovite shreds. The quartz anhedra form well defined areas, filling the feldspar interspaces. Twinning among the various feldspar species, according to the Carlsbad, albite and pericline laws, is quite common and characteristic. With the exception of the biotite, all the essential groundmass minerals are allotriomorphic in outline. Orthoclase is present as idiomorphic crystals porphyritically developed, and as allotriomorphic grains in the groundmass. The feldspar phenocrysts enclose, in addition to the biotite, irregular grains of quartz and other feldspars. Biotite is the chief accessory mineral, and has a deep-brown to yellowish-brown color, good basal cleavage, and strong absorption, and is intergrown with some muscovite. It is more or less altered to dark-green, opaque chlorite, and, to a less degree, to a slightly brownish, pleochroic epidote. Inclusions of prismatic apatite and zircon, with small ovals of micropegmatitic intergrowths of quartz and feldspar, are usually present.

The chemical composition of this rock is shown in the following analysis, made by the writer in the Survey laboratory:—

Silica, SiO_2	70.24
Alumina, Al_2O_3	16.78
Iron Sesqui-oxide, Fe_2O_3	1.46
Lime, CaO	2.00
Magnesia, MgO	0.76
Soda, Na_2O	3.70
Potash, K_2O	5.03
Ignition	0.50
Total	100.47

A weighed portion of the finely-powdered fresh rock, digested for three hours in 100 c.c. of boiling half-normal hydrochloric acid, gave 9.91 per cent. of soluble material.

Compare the above analysis with analyses of porphyritic granites from Baldwin, Columbia, Greene, Hancock, Coweta and Fayette counties, Georgia, and the percentages of the various constituents are readily seen to be remarkably uniform. The rock, in the hand specimen, also closely resembles that from Baldwin, Columbia and Greene counties. The ratio of phenocryst to groundmass in the Pike County granite, for the area as a whole, is very much smaller than for the same rock in the counties mentioned above. The porphyritic facies is only developed in small, local areas through the rock-mass, which is, for the most part, an even-grained granite.

The weathering of this rock is, in every way, similar to that of the porphyritic granites in the above named counties. The feldspars crumble in part from kaolinization, and, in part, they split up into smaller particles along the cleavage planes; and the entire mass is more or less discolored from the oxidation and leaching of the biotite shreds. By a continuation of this process, which is both physical and chemical, the fresh rock is finally resolved into a coarse-grained, granitic sand composed of grains of the component minerals, feldspar, quartz and mica.

SPALDING COUNTY

Spalding county lies immediately north of Pike county, and areas of both granite and granite-gneiss, suitable for various grades of work, occur. Quarrying has been limited to outcrops occurring outside of the northern limits of Griffin, the county-seat of Spalding.

At Rocky Branch, where the stream is crossed by the Zebulon-Griffin public road, three miles south from Griffin, there are flat-surface outcrops of a medium coarse-grained biotite gneiss. Horizontal-surface outcrops, containing three to six acres in the exposure, occur in the stream-bed and on both sides of the stream. No stone has been quarried at this locality.

THE TURNER QUARRY. — This quarry is located one mile a little west of north from Griffin, on the east side of, and about 100 yards from, the Central of Georgia railway, along a small ravine. About two acres of surface outcrops are exposed as horizontal sheets. The quarry was opened some years ago, and a large quantity of the rock was quarried for use along the Central of Georgia railway. Some three or more successive "raises" have been made, and the stone has been worked up. Small stained areas occur in places in the rock along the quarry face, resulting from the decomposition of the magnetite (an iron oxide) grains present.

The rock is a medium coarse-grained biotite granite, carrying a fair quantity of muscovite. When broken in a certain direction, the rock shows a re-arrangement of the mica and light-colored minerals along approximately parallel lines, imparting somewhat of a schistose structure. In the hand specimen, some of the feldspar grains show a slight porphyritic tendency; are usually twinned according to the Carlsbad law; and have good cleavage. Muscovite is more abundant in the hand specimen, than under the microscope, in thin section. The component minerals are readily recognized macroscopically.

Studied in thin section under the microscope, the rock is a coarse-grained biotite granite, consisting of an aggregate of interlocking grains of quartz, and the feldspar species, orthoclase with some microperthitic intergrowths, microcline and plagioclase, with intergrown foils of biotite and some muscovite. The quartz is usually present as a coarse-grained mozaic occupying well defined areas, and also as single grains filling the feldspar interspaces. The orthoclase is frequently intergrown with a second feldspar in microperthitic structure; and, in some cases, it shows good cleavage development parallel to the base (001) and the clinopinacoid (010). The microcline displays the characteristic grating structure, and encloses numerous rounded, drop-like inclusions of quartz, and other feldspar species. Some plagioclase with rudely lath-shaped outlines, and polysynthetically twinned, occurs. Twinning according to the Carlsbad law is also common to the potash feldspars. Biotite occurs as stout intergrown foils of medium color and strong absorption, and is intergrown at times with muscovite shreds. It commonly carries microscopic inclusions, mostly zircon crystals. Prismatic inclusions of apatite are common to some of the feldspar grains. Micropegmatitic intergrowths of quartz and feldspar are quite common.

The chemical composition of this rock is shown in the following analysis made by the writer in the laboratory of the Geological Survey: —

Silica, SiO_2	69.07
Alumina, Al_2O_3	16.56
Iron Sesqui-oxide, Fe_2O_3	1.37
Lime, CaO	1.83
Magnesia, MgO	0.76
Soda. Na_2O	4.66
Potash, K_2O	5.02
Ignition	0.92
Total	100.18

Located one mile north of Griffin on the Camp Stevens wagon-road and on the south side of a ravine, a quarter of a mile due west from the Turner quarry, are outcrops of the same granite. These are near the foot of a long hill sloping 30° to 35°, and occur along the lower slope and ravine, on each side of the wagon-road, and over most of the hillside. A slight surface-stripping has been made at one point on the east side of the road, where a few rocks have been quarried.

The rock is a medium coarse-grained light-gray biotite granite, displaying a slight schistose structure. It is the same rock as that quarried at the Turner quarry, except that it contains somewhat less muscovite and magnetite.

THE BEECHER QUARRY. — This quarry is located just back of the cotton mills along the course of a small stream, between the Turner quarry and the rock-outcrops found along the Camp Stephens wagon-road. The granite outcrop includes several acres in extent, with small openings made in several places; and a small amount of the rock has been quarried. Another outcrop of the same rock occurs near the cotton mill along the Central of Georgia railway. The rock is a medium coarse-grained, light-gray biotite granite, composed of quartz, feldspar, biotite and muscovite; and is the same body of granite as that in which the Turner quarry has been opened. An 8-inch cube collected from this quarry and now on exhibition in the State Museum at the Capitol in Atlanta, shows that the rock takes a high polish and works well under hammer. It also possesses strong enough contrast between the polished and hammered surfaces, along with the texture and color, to render it a fairly desirable rock for monumental purposes.

THE DICKERSON PLACE. — This property is located seven miles from Griffin in the Mt. Zion district, and two-thirds of a mile from the Atlanta & Florida R. R. (Southern railway). Some twenty acres of exposed rock are found on the place. No regular or systematic quarrying has ever been attempted. The rock is a medium coarse-grained dark-colored biotite granite, of good quality. It contains an increased amount of biotite over similar rocks occurring in Spalding county, and is accordingly darker in color. A part of the feldspathic constituent displays a slight tendency towards porphyritic development in places. An 8-inch cube, polished and hammer-dressed, on exhibition in the State Museum at the Capitol Building in Atlanta, indicates the excellent qualities of this granite.

FAYETTE COUNTY

The granitic rock of Fayette county consists of the porphyritic type, occupying the central, northern and western portions of the county; and represents, in the outcrops near Line creek in the western part of Fayette, an extension of the porphyritic granite occurring near Coweta station in Coweta county, and Palmetto in Campbell county. No regular quarries have been opened; but some rock for local purposes, such as chimneys, foundations etc., has been obtained, from time to time at numerous places in the county.

THE A. J. MCELWANEY PLACE.—Ten miles west from Fayetteville and five miles east from Coweta station, on the Atlanta and West Point railroad, is an extensive outcrop of a coarse-grained porphyritic granite. The outcrop is about one hundred yards east of Line creek, which stream marks the boundary between Fayette and Coweta counties, and is located directly on the north side of the Fayetteville-Newnan public wagon-road. The exposure contains approximately eight acres in all, and lies mostly in one flat-surface mass, although a few boulder outcrops are nearby. The only work done consists of a small amount of stone stripped from the surface for chimneys, in the immediate neighborhood. The rock contains numerous rounded areas, six inches and more in diameter, of fine-grained, dark-colored, slightly porphyritic segregations, composed principally of biotite, with feldspar as the porphyritic mineral. These areas are not extensive enough, however, to, in anywise, damage the rock.

The rock is a coarse-grained, porphyritic biotite granite, of uniform character and excellent quality. White, opaque orthoclase occurs as the porphyritic mineral. The phenocrysts are 15 to 25 millimeters long, tabular parallel to the clinopinacoid (010), and usually twinned according to the Carlsbad law. Twinning in the feldspar phenocrysts of this rock, however, is less frequent than in some of the other porphyritic granite areas in the State. Feldspar is the most abundant mineral present, with quartz next. The quartz is slightly dark in color, the grains measuring 5 to 10 millimeters in length. The biotite is present as stout plates, measuring 3 to 4 millimeters in diameter, and is very black in color. The marked characteristics of the component minerals, which are in strong contrast with each other, render them easily identifiable in the hand specimens.

Microscopically, the rock is a coarse-grained porphyritic biotite-granite, composed of quartz and the feldspars, orthoclase with microperthitic structure, microcline and soda-lime feldspar (plagioclase), with biotite and a few shreds of intimately associated muscovite. The groundmass consists of a coarse-grained mozaic of feldspar, quartz and biotite. The porphyritic mineral is microperthitic orthoclase, usually enclosing irregularly shaped grains of quartz, feldspar and biotite, variously orientated. Some of the groundmass feldspar crystals are twinned according to the Carlsbad law, and are allotriomorphic in outline and somewhat altered. Biotite occurs as aggregated intergrown shreds with deep color and strong absorption, and to some extent is altered to chlorite and epidote. Micropegmatitic intergrowths of quartz and feldspar, and prismatic inclusions of apatite are frequently observed. In addition to the few primary shreds, secondary muscovite, resulting from feldspathic alteration, occur. The quartz and feldspar indicate the usual strained condition from the numerous fracture planes crossing the crystals.

The chemical composition of the rock from this locality is indicated in the following analysis, made by the writer in the Survey laboratory: —

Silica, SiO_2	70 88
Alumina, Al_2O_3	15.86
Iron Sesqui-oxide, Fe_2O_3	1.77
Lime, CaO	1.79
Magnesia, MgO	0.93
Soda, Na_2O	3.94
Potash, K_2O	4.64
Ignition	0.49
Total	100.30

Specific Gravity	2.659
Weight of one cubic foot of stone expressed in pounds	166.18
Number of cubic feet contained in one ton (2,000 pounds)	12.0

This rock is somewhat lighter in color than its correlative occurring just across the line in Coweta and Campbell counties. The chemical analysis accordingly indicates a slight decrease in biotite and a corresponding increase in free quartz in this, over the similar McCollum and Palmetto rocks, in Coweta and Campbell counties.

Weathering is promoted by hydration and oxidation, and the rock is accordingly reduced to a coarse-grained, rusty colored granitic sand, by both physical and chemical agencies.

THE BENNETT'S MILL ROCK. — Two and a quarter miles west from Fayetteville, at Mr. C. E. Bennett's mill, are numerous boulder outcrops of a porphyritic gneissoid granite carrying an abundance of black biotite. The rock is medium coarse-grained in texture, and contains a greater proportion of biotite than the McElwaney granite described above, and is correspondingly darker in color. The rock begins to outcrop as large boulders on each side of the public road, one and a quarter miles west of Fayetteville, and is more or less continuous to the McElwaney rock near Line creek, a distance of some eight to nine miles. It has a decided banded or schistose structure, due to a re-arrangement of the mica folia along approximately parallel lines.

In many places along the road-side, the residual decay from the porphyritic rock, is seen to good advantage in sections, twenty-five and more feet in depth, without any trace of the fresh, or even partially fresh rock, shown. The decay is a medium vari-colored ferruginous clay, containing the embedded white, kaolinized feldspar phenocrysts of the fresh rock still intact, which impart a beautiful mottled appearance to the clayey mass.

CAMPBELL COUNTY

Extensive areas of fine, even-grained biotite granite and coarse-grained porphyritic granite, of excellent quality, occur in Campbell county, limited, for the most part, to the southern and eastern sections of the county. These areas represent, as is shown by field- and laboratory-study, the northern equivalents of more extensive outcrops of the same rocks, southward in Coweta and Fayette counties; more especially, in Coweta, elsewhere described in this report. They are, therefore, correlated parts of the same granite masses. Granite quarrying has been very limited, in this county. It is restricted to two localities in the immediate vicinity of the towns of Palmetto and Fairburn, along the Atlanta and West Point railroad.

THE PALMETTO AREA.—The granite found in this section consists entirely of the coarse-grained porphyritic type, outcrops of which occur to the south of Palmetto, near Coweta station in Coweta county, and again to the southeast in Fayette county, near Line creek. A half-dozen or more outcrops, in the form of boulders and flat-surface masses of the porphyritic granite, occur within a radius of from three to four miles. It is quite uniform in character throughout the area, and some rock has been quarried from several of the exposures for local purposes.

Two miles southwest of Palmetto, on Mrs. M. A. E. Steed's place, and near the head-waters of a small stream, occur flat-surface exposures of the porphyritic granite. Some of the rock from this locality was quarried for local use, many years ago. In the outcrop, the rock indicated at the surface an advanced stage of decay, which rendered it almost impossible to obtain fresh specimens. The porphyritic feldspar phenocrysts are two or more inches in length; and they are commonly twinned according to the Carlsbad law.

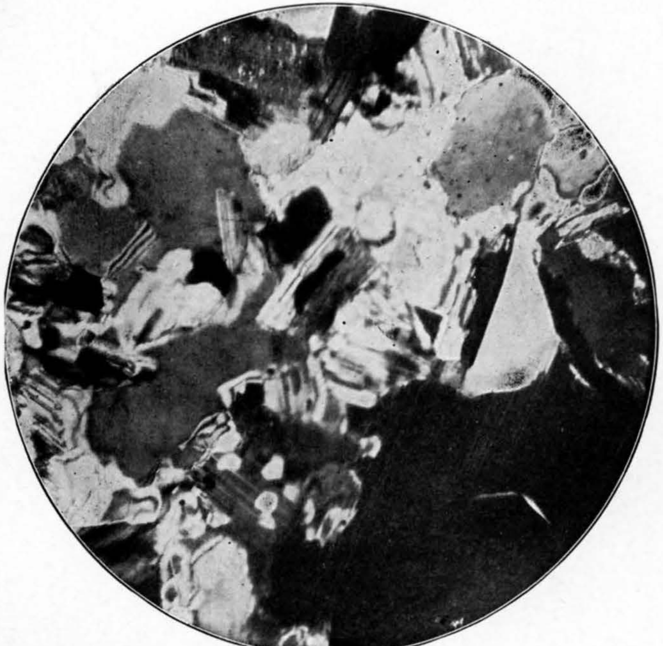


FIG. 1. PHOTO-MICROGRAPH OF THE LIGHT-GRAY GRANITE, FROM STONE MOUNTAIN, DEKALB COUNTY, GEORGIA.
Crossed Nicols x 74.

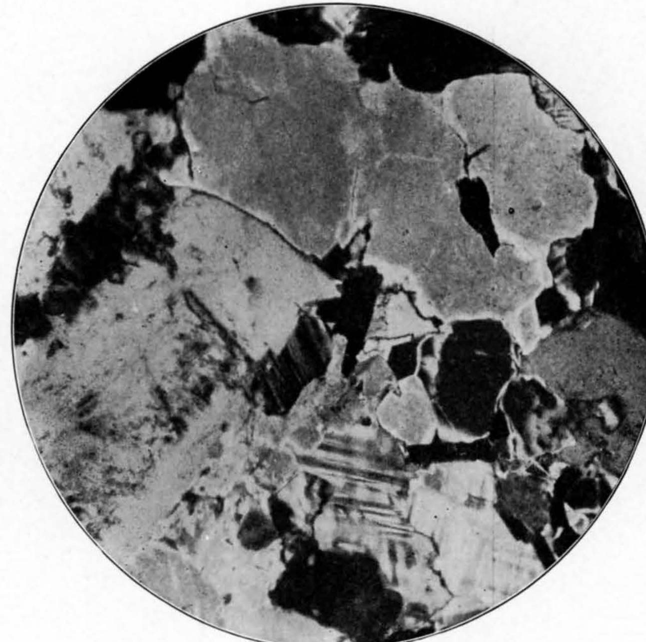


FIG. 2. PHOTO-MICROGRAPH OF THE CONTORTED BIOTITE GRANITE-GNEISS, FROM THE CROSSLEY QUARRY, NEAR LITHONIA, DEKALB COUNTY, GEORGIA.
Crossed Nicols x 74

Outcrops of the same rock occur near the wagon-road in Mr. Ed. Daniels' field, approximately one and a half miles southwest from Palmetto, on the place adjoining Mrs. Steed's.

The main track of the Atlanta and West Point railroad crosses large outcrops of the porphyritic granite for several hundred yards to the north of Palmetto depot, and as far south as Coweta station a distance of five miles.

A large boulder outcrop of this granite occurs three-quarters of a mile east from Palmetto, on Mr. W. G. Williams's place, on the south side of and near the public wagon-road.

On Dr. H. L. Johnson's place, half-a-mile east from Palmetto, and on the north side of the wagon-road, occurs a large boulder outcrop of the coarse-grained porphyritic granite, in which the feldspar phenocrysts are unusually large and stout. This outcrop has been worked, and the stone used in building the ware-house at Palmetto depot. The rock remains very homogeneous in character, and is cut by several pegmatitic veins.

Another exposure of the same rock is seen three-quarters of a mile north of Palmetto, near the contact of the porphyritic granite mass with that of a large body of mica-schist.

Megascopically, the rock is a very coarse-grained porphyritic biotite granite, of medium-gray color. Owing to the extreme coarseness of texture, the porphyritic structure is not altogether so typically marked as in finer-grained rocks. The porphyritically developed mineral (feldspar) grades imperceptibly from the very large irregular and sometimes stout tabular phenocrysts into the groundmass minerals, making it difficult usually to distinguish between groundmass and phenocryst feldspar, except in extreme cases. The porphyritic feldspar varies from extremely irregular crystals, 30 by 30 millimeters, with good cleavage and abundant inclusions of biotite, to somewhat idiomorphic crystals, tabular parallel to the clinopinacoid (010), and twinned according to the Carlsbad law, with cleavages parallel to the base (001) and clinopinacoid (010). The feldspars are invariably white in color. The biotite occurs in somewhat well defined areas, averaging 10 to 15 millimeters in diameter, very black in color, and highly lustrous; while the coarse vitreous quartzes stand out in moderate relief from the feldspar and mica. Microscopic examination indicates, that the potash feldspar is the porphyritically developed species—either orthoclase or microcline, or both.

Microscopically, thin sections of the rock (Museum Nos. 1,890 and 1,891) revealed a very coarse-grained, porphyritic rock, in which no sharp line or marked differentiation between groundmass and phenocryst appears. The porphyritically developed mineral (feldspar) grades imperceptibly, as regards size, from phenocryst on the one extreme to that of the groundmass on the other. The feldspar constituent consists of the potash species, orthoclase and microcline, and lime-soda plagioclase, which, from its optical properties, is near oligoclase. When taken together, the feldspar constituent is greatly in excess of the quartz and biotite, which becomes feldspar > quartz > biotite.

A thin section, made from a hand specimen of the rock, collected from Dr. Johnson's place, showed no microcline present. Some of the orthoclase contains marked microperthitic intergrowths of a second feldspar, albite. The feldspar and quartz are entirely allotriomorphic-granular. Biotite occurs as large, stout aggregated plates with the usual characteristic brown color and strong absorption, and is occasionally intergrown with foils of muscovite. Inclusions are usually common in the biotite. Epidote, muscovite and some chlorite occur as secondary minerals derived from the partial alteration of the feldspar and biotite. Apatite inclusions are frequently observed.

A thin section of one of the feldspar phenocrysts from the Johnson rock showed the characteristic microcline structure under the microscope. The complex albite-pericline twinning, producing the characteristic microcline (gridiron) structure, was typically developed. Some biotite shreds and several large microscopic crystals of plagioclase were present, as inclusions in the microcline phenocrysts.[1]

The rock weathers principally by means of disintegration, producing granulation through temperature changes, which is aided to some degree by chemical decomposition, shown in a partial kaolinization of the feldspars, rendering them dull and opaque, and in the partial oxidation and subsequent leaching of the iron oxide of the biotite, discoloring the mass a rusty color.

THE FAIRBURN AREA.—The type of granite occurring near Fairburn, the county-seat of Campbell county, is a medium-fine and even-grained, massive, light-gray biotite granite, well suited for building and monumental work. Small quantities of the rock have been quarried, from time to time, for local use, from several of the outcrops. The only quarry, at present producing rock for shipping purposes, and not strictly for local use, is that recently opened on the old Westbrook estate, owned by his daughter, Mrs. Cora J. Carmichael.

[1] For chemical analyses and further description of the southern portions of this rock area, see under granites of Coweta and Fayette counties, pages 92, 93 and 103.

MRS. CORA J. CARMICHAEL'S QUARRY. — This quarry is located two and a quarter miles N. 25° E. from Fairburn, and a quarter of a mile east from the Atlanta and West Point railroad. It was leased for five years, beginning May, 1898, by the Patterson Brothers, of Atlanta, when it was first opened for the quarrying of coping and monumental stone for the cemetery in Jacksonville, Florida. The rock outcrops as boulders over some ten to fifteen acres of ground, a number of which have been worked up. Up to the time of the writer's visit, June, 1899, it was estimated, that thirty-five cars of stone had been shipped. Derricks for handling the stone were intact, and it was one of the few quarries in the State working at that time. The right-of-way has been obtained, and it was the intention of the lessees to put in a side-track from the Atlanta and West Point railroad to the quarry. The rock extends to and across the railroad, and is exposed in several places along the track of the above road.

Megascopically, it is a very uniformly even and fine-grained, medium light-gray biotite granite, in which the quartz, feldspar and mica are readily distinguished in the hand specimen. The quarry area is cut by a northwest-southeast set of joint-planes, which are more or less smooth and slicken-sided along their surfaces, indicative of some movement. A few veins of slight dimensions were also observed. The rock is susceptible of a high polish, and is admirably adapted to monumental and general building purposes.

Under the microscope, a thin section of this rock (Museum No. 1,888) indicated a fine-grained, allotriomorphic-granular granite, composed of an admixture of interlocking quartz and the feldspar species, orthoclase with microperthitic structure, microcline and plagioclase, with single scattered plates of biotite occasionally intergrown with foils of muscovite. The feldspar constituent makes up more than 60 per cent. of the total rockmass. The quartz has its usual characteristic occurrence, as in rocks of this type. Some micropegmatitic intergrowths of quartz and feldspar occur. The biotite is variously altered to a green and brown colored, opaque chlorite, and a pleochroic, highly double-refracting epidote. Considerable muscovite and epidote occur, as secondary minerals. The essential minerals are characterized by an allotriomorphic outline.

Mechanical strain is manifested to some degree in the thin section, in slight peripheral shattering of the larger quartz and feldspar grains, and in marked undulous extinction and numerous lines of fracture crossing the larger feldspar and quartz individuals.

A chemical analysis of the rock from this quarry yielded the writer, in the laboratory of the Geological Survey, the following results:—

Silica, SiO_2	69.55
Alumina, Al_2O_3	16.72
Iron Sesqui-oxide, Fe_2O_3	0.99
Lime, CaO	1.69
Magnesia, MgO	0.27
Soda, Na_2O	5.88
Potash, K_2O	3.94
Ignition	0.27
Total	99.31

A comparison of this with analyses of the similar rock from the Sam Hill and R. D. Cole quarries in Coweta county, shows very close agreement in chemical and mineral composition. A large part of the stone, used in the building of the new church in Fairburn, came from this quarry.

Other tests made yielded the following results:—

Specific Gravity at 24° C.	2.658
Weight of one cubic foot of stone expressed in pounds	166.12
Number of cubic feet of stone contained in one ton (2,000 pounds)	12.0

From a half to three quarters of a mile east from the Carmichael quarry, on the Westbrook place, occur outcrops of the same rock, from which some stone is said to have been quarried for chimneys some years ago. Outcrops of a similar granite occur as far north as 4 miles from Fairburn on the Atlanta and West Point railroad.

On Mr. W. T. Roberts' place, one and a quarter miles southeast from Fairburn, just off the Senoia wagon-road, occurs a fairly large boulder outcrop of the same granite as that described from the Carmichael quarry. The outcrop has been partially worked. It is cut by veins and joint-planes.

Microscopically, a thin section of this rock (Museum No. 1,897) showed a fine-grained, allotriomorphic-granular biotite granite, composed of microperthitic orthoclase, microcline and plagioclase feldspars and quartz, with shreds and foils of biotite, more or less altered to chlorite and some epidote. The microscope further indicates that the quartz and feldspars crystallized simultaneously, as the two minerals mutually interfered, and in many cases, are intergrown in the form of micropegmatitic structure. Marked zonal structure is common to many of the feldspar crystals.

Twinning is quite common among the feldspars present. Epidote, chlorite and muscovite, as secondary products or minerals, and primary inclusions of apatite crystals, occur. Irregular double-refraction, lines of fracture, and small crushed areas of quartz and feldspar indicate more or less mechanical strain.

At Mr. U. E. Humphries' place, approximately one mile east of Fairburn, outcrops of the same rock occur, from which stone for foundations and other purposes, for buildings in Fairburn, were gotten.

The granites are associated with large bodies of mica-schist, which is the prevailing country-rock. While no definite contact between the two rocks could be entirely established, on account of the heavy covering of residual decay, other field relations strongly indicate, that the granite was intrusive in the mica-schist.

Résumé of the Granitic Rocks of Campbell, Coweta, Fayette, Heard, Meriwether, Pike, Spalding and Troup Counties

As may be seen from the above detailed description of the granitic rocks occurring in these counties, extensive workable areas of different grades of granite are found, thoroughly suited for all classes of work, in which granite is used. The distribution of the granite in the above counties may be seen by referring to the map opposite page 65. Practically no systematic quarrying has been carried on, in any part of the above section; although quite a large supply of rock has been quarried for purely local purposes, from time to time, covering a period of some 15 to 20 years, which has resulted in the partial development of a goodly number of small quarries. Only a very limited supply of the rock has been shipped outside of the State. The outcrops are usually of large dimensions, and practically free from soil-covering. The quarries opened are well located with reference to transportation facilities by rail, and admit of easy working. The most extensive areas of the rock and the largest quarries are found mostly in Coweta and Meriwether counties.

The rock consists of fine, even-grained, medium- to dark-gray biotite granite; coarse-grained, porphyritic biotite granite; and biotite granite-gneisses. In texture and structure, the rocks vary from massive, even-granular, through coarse-grained, porphyritic granites, to highly schistose and laminated granite-gneisses. They vary but slightly in color, having usually a medium to dark-gray tone. In mineral and chemical composition, the three types show practically no variation, but are remarkably close and uniform. Mineralogically, they are composed of quartz and the feldspars, orthoclase containing nearly always some microperthitic structure, microcline and plagioclase, with biotite as the characterizing accessory mineral, associated usually with more or less muscovite. The relative abundance of the component minerals may be expressed as follows: Feldspar including all species > quartz > biotite > muscovite. The component mineral grains are closely and complexly interlocked, imparting thereby great strength and durability to the stone.

Representative 8-inch cubes of the three granite types, collected from the principal quarries in this section of the State, polished and hammer-dressed, on exhibition in the State Museum at the Capitol in Atlanta, show the excellent finish these granites are capable of receiving.

The chemical relation of these rocks is readily brought out in the following table:—

	I	II	III	IV	V	VI	VII
SiO_2 . .	63.27	63.65	66.92	68.38	69.08	69.55	69.88
Al_2O_3 .	19.93	20.46	18.19	17.79	17.67	16.72	16.42
Fe_2O_3 .	2.82	2.20	3.05	1.21	1.41	0.99	1.96
CaO . .	2.89	3.38	4.95	2.85	3.27	1.69	1.78
MgO . .	0.49	1.50	1.26	0.72	0.64	0.27	0.36
Na_2O . .	4.14	4.75	3.83	4.36	4.56	5.88	4.46
K_2O . .	4.85	4.58	2.02	3.57	3.29	3.94	5.63
Ignition .	0.86	0 42	0.46	0.78	0.56	0.27	0.36
Total .	99.25	100.94	100.68	99.66	100.48	99.31	100.85

	VIII	IX	X	XI	XII	XIII	XIV
SiO_2 . .	69.07	70.24	70.88	73.95	74.80	74.96	76.37
Al_2O_3 .	16.56	16.78	15.86	14.23	15.46	13.71	13.31
Fe_2O_3 .	1.37	1.46	1.77	1.29	1.04	0.90	1.21
CaO . .	1.83	2.00	1.79	1.07	0.82	1.02	1.13
MgO . .	0.76	0.76	0.93	0.23	0.11	0.24	0.10
Na_2O . .	4.66	3.70	3.94	4.61	4.80	4.68	4.02
K_2O . .	5 02	5.03	4.64	5.29	2.52	4.79	3.68
Ignition .	0.92	0.50	0.49	0.25	0.31	0.44	0.20
Total .	100.19	100.47	100.30	100.92	99.86	100.74	100.02

I Analysis of granite from the T. B. Tigner quarry, Meriwether county.
II Analysis of porphyritic granite from the McCollum quarry, Coweta county.
III Analysis of grano-diorite-gneiss near Grantville, Coweta county.
IV Analysis of granite from the Sam Hill quarry, Coweta county.
V Analysis of granite from the Cole quarry, Coweta county.
VI Analysis of granite from the Carmichael quarry, Campbell county.
VII Analysis of granite from the Greenville quarry, Meriwether county.
VIII Analysis of granite from the Turner quarry, Spalding county.
IX Analysis of porphyritic granite from Flat Rock, Pike county, 9 miles west of Zebulon.
X Analysis of porphyritic granite, near Line creek, Fayette county.
XI Analysis of granite-gneiss from Flat-rock quarry, Coweta county.
XII Analysis of granite-gneiss from Flat Shoals, Meriwether county.
XIII Analysis of granite-gneiss from Flat-rock, Heard county.
XIV Analysis of granite-gneiss from Odessa quarry, Meriwether county.

Absorption tests, made on two specimens of granite from Meriwether county, yielded the following figures:—

Percentage (ratio) of absorption	0.086 (Greenville)
" " "	0.056 (Odessa)

These figures are in close agreement with similar tests made on granites occurring in other sections of the State, and indicate, that the stone from this area is likely to suffer but slightly from the freezing of absorbed water—frost action.

A careful examination of the natural outcrops of the rock in the field, shows, that the stone begins to weather from temperature changes and hydration, and in many cases, it is resolved by these agencies into an incoherent mass of granitic sand, which is but slightly stained or discolored by iron oxide, derived principally through oxidation from the iron-bearing minerals present. This serves to illustrate the slight effect of chemical forces, active in the early stages of weathering; and it further shows, that the rocks of this type are damaged principally through mechanical agents. The final limit in the decay of these rocks results in a highly ferruginous, deep-red, stiff clay as a residual product.

The prevailing country-rock is a thinly fissile mica-schist, in immediate contact with the granites, which, from the relationship of the two rocks, indicates, that the granites have been intruded into the schist, and exposed subsequently by denudation. The schists are also cut, in numerous places, by a younger series of basic eruptive rocks, diabases.

DEKALB COUNTY

The most extensive areas of exposed granite and granite-gneiss in the State occur in DeKalb county, including the famous Stone Mountain and Lithonia areas. Other outcrops of granite are found in places over the county; but they are by no means so large and important, as those mentioned above. As early as 1845 or 1850, some evidence that granites were worked into tombstones, is apparent in the country church-yards; but nothing authentic can be learned regarding the first development of the granite industry. Records show, however, that some granite was quarried at Stone Mountain before the Civil War. The first effort toward a systematic introduction of the Georgia granite seems to have been made by the Stone Mountain Granite and Railway Company, operating at Stone Mountain, between the years 1869 and 1882. This company was succeeded by the Venable Brothers in 1882, to whose efforts the present popularity of the Georgia granite is directly traceable.

In the Stone Mountain-Lithonia section, the granitic rocks are exposed at the surface, in the form of huge bosses which measure several miles in circumference at their bases, and rise in the case of Stone Mountain, to an elevation of 686 feet above the surrounding country.

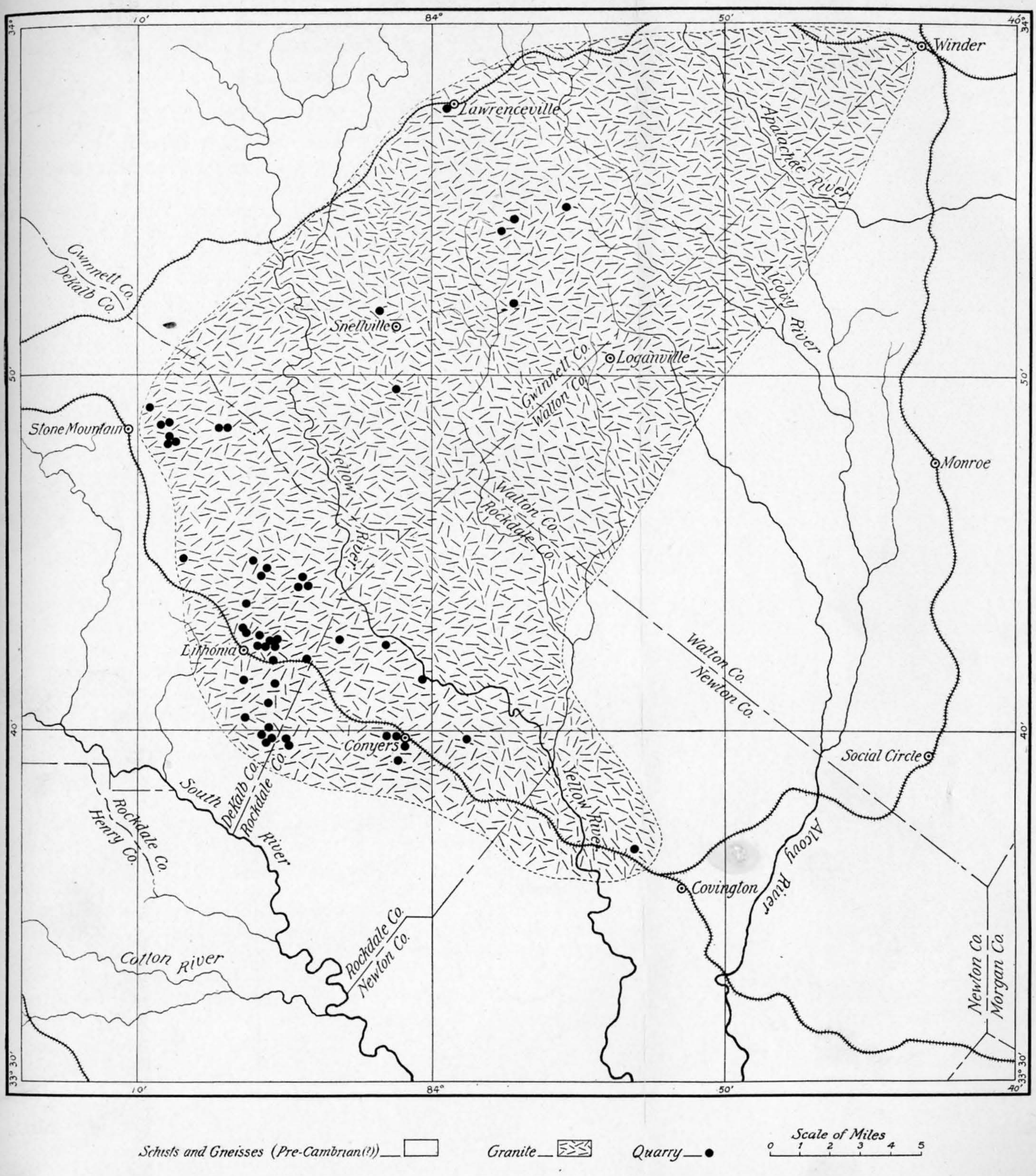
Stone Mountain proper, Pine (Little Stone Mountain), Collinsville, Arabia, Rock Chapel and McDaniel mountains form distinct bosses, rising to conspicuous elevations above the surrounding lowland plane. All these, with the exception of Stone Mountain, are composed of highly contorted, light-gray biotite granite-gneiss, of remarkably uniform texture and composition, and form a part of the well-known Lithonia belt of contorted granite-gneiss.

With the exception of a few stunted or diminutive pines and cedars, moss and lichens, the bosses (mountains as they are locally termed) are entirely barren of verdure. They are free from soil, save along some of the jointing surfaces, where partial disintegration has taken place, and enough of the residual earth has been left, to sustain the scanty plant growth mentioned above.

That the present huge boss of granite, appropriately named Stone Mountain, is but the remnant of a once existing, much larger granite mass, is shown in the numerous outcrops of the same rock extending over a belt, several miles in width, of a moderately undulating, nearly flat surface immediately skirting the present mass. This is more especially true of the east, north and south sides of the ridge. Quarries yielding the same grade of excellent light-gray granite have already been opened in some of the larger and more favorably located outcrops in the border zone. It would seem, as is held by Dr. George P. Merrill, that the existing boss, Stone Mountain, owes its present form to exfoliation.

Stone Mountain creek flows directly across the lowland belt of dissected granite, near the northern and eastern sides of the ridge proper, and is tributary to Yellow river. The former stream is joined near the eastern limits of the ridge by a smaller stream, which heads just outside of Stone Mountain village, and maintains its course close to the southern and eastern base of the mountain. These streams, especially the larger one, Stone Mountain creek, have greatly aided in the reduction of the present immediately adjacent lowland plane.

Stone Mountain forms one of the few conspicuous, unreduced, residual masses found rising above the general surface-level of the Georgia Piedmont-Tertiary peneplain. That this and the adjacent masses of hard contorted granite-gneiss, in the Lithonia area to the south, were not reduced to the same approximate level of the surrounding plane, can be readily accounted for, by differential rock-hardness, and remoteness from the major streams in the region.



MAP OF THE DEKALB-ROCKDALE-GWINNETT GRANITE AND GRANITE-GNEISS AREA.

STONE MOUNTAIN AND ITS QUARRIES.

This noted granite property, owned and controlled by Messrs. Venable Brothers of Atlanta, is located about 16 miles east of Atlanta in the eastern part of DeKalb county on the Georgia railroad. The entire property includes some 2,200 acres. The huge dome-shaped ridge rises 686 feet above the adjacent lowland plane; measures seven miles in circumference at its base; and includes 563 acres in the exposed granite mass. It is certainly the most striking geological phenomenon in the Eastern United States, and surpasses anything of its kind yet known in the way of exposed granite.[1] It is stated, that a careful estimate made by a competent engineer of the exposed granite in the mass above the surface-level of the plane is placed at 7,543,750,950 cubic feet.[2] The boss is elliptical in shape, with its longest axis trending northwest-southeast, and its steepest side facing northward.

Records show, that some rock was quarried from the somewhat disintegrated and decomposed ledges of the ridge as early as 1845 to 1850. The first systematic quarrying, however, was begun in 1869, when the Stone Mountain Granite and Railway Company was chartered by Messrs. John T. Glenn, S. M. Inman and J. A. Alexander, citizens of Atlanta. In 1882, the present owners, Messrs. Venable Brothers, of Atlanta, purchased the entire property of 2,200 acres, and immediately began developments for extensive quarrying. The annual output outside of the State rapidly increased from ten car-loads, under the management of the former company, to twenty thousand car-loads under that of Messrs. Venable Brothers.

It was through the efforts of Messrs. Venable Brothers, that the development of this property gained for Georgia the high rank and reputation, the State now holds among the other granite-producing States in the Union, as a granite producer. For some years, DeKalb county, limited exclusively to the output from the Stone Mountain and Lithonia areas, produced all the granite shipped outside of the State; and, in amount of production, it has always ranked first among the numerous granite-producing counties in the State.

Numerous quarries, yielding most excellent and beautiful stone, have been opened and extensively worked along the western and southern flanks of the ridge. Notwithstanding the very large amount of stone quarried for building and street purposes, and to some extent for monumental stock, and shipped to the principal towns and cities in the south and west, the appearance of the ridge

[1] See Plate I; also, Purington, C. W., American Geologist, 1894, Vol. XIV, pp. 105–108.

[2] GRANITE PAVEMENTS; compiled by Venable Brothers, Atlanta, Ga.; 1893.

barely indicates a beginning in the quarrying industry. The doming mass is apparently formed of layers of varying thicknesses, leaving no visible lines of separation, except at the surface, where it has been subjected to weathering. These are cut at right angles by a well defined set of joint planes, which, in connection with the slope, afford superior facilities for easy quarrying. Every facility, in the way of modern equipment for work, such as engines, boilers, steam-drills and other appliances and machinery, has been added. Some eight miles of railway are operated from the main line of the Georgia road at Stone Mountain station to and around the base of the ridge. The equipment is probably equal in all essentials to that of any of the larger quarries in the East; and this renders the company abundantly able to handle, with considerable ease, stone of any desired dimensions and shape. As opened in 1893, the Stone Mountain quarries were capable of yielding a total capacity of 25,000 paving-blocks per day. At present, this can be increased to any desired output.

As seen from the chemical and physical tests below, the stone is thoroughly adapted to all kinds of structural and street work. It has been employed most extensively as a building-stone, and almost as largely as a street material, in the form of blocks and curbing; also, to a much less extent, as monumental stock. It has been shipped to most of the principal towns and cities in the south and west, where it is used as a paving and building stone. Some of the handsomest massive structures in the above sections are built in whole, or in part, from this granite.

Macroscopically, the rock is an even-textured, medium-grained, light-gray, biotite-bearing muscovite granite. Practically no variation in color, texture and composition is observed throughout the mass; but, on the contrary, the rock remains remarkably uniform over the entire area. Two sets of well defined joint-planes, cut the granite mass, but jointing structure is by no means as characteristic of Stone Mountain as of other granite masses. The planes, where observed, show nearly equal development. One set has a northwest-southeast direction, with the other cutting this set at approximately right angles. Some movement is indicated in the mass by the highly slickensided surfaces of the joint-planes. These are coated with damourite, which distinctly shows the striations produced by the movement. The rock is further cut by pegmatitic veins, which vary in width from a fraction of an inch to 18 inches. These have the characteristic vein structure. They have no definite directions; but they cut indiscriminately, and are composed mainly of quartz and feldspar, with some tourmaline, biotite, muscovite and garnet. Several small knife-edge veins of fibrous, felt-like tourmaline were observed on the floor of the Hayne (pronounced *Hay-ne*) quarry.

In some of the quarries, the surfaces of the major joints are coated in some cases with a lemon to sulphur-yellow incrustation. This incrustation, thinly coated by hyalite, is particularly abundant on the jointing surfaces exposed in the Hayne quarry, located on the northwest side of the ridge. The hyalite forms a clear, colorless, glassy coating over the surface of the uranophane. The yellow mineral was examined chemically some years ago in the laboratory of the Geological Survey by Mr. R. L. Packard. In his report to Prof. W. S. Yeates, State Geologist, by whom it had been submitted for examination, he says :—

"The yellow incrustation on the granite was examined by the blow-pipe and gave reactions for uranium. A qualitative examination in the wet way showed lime and phosphoric acid. Misled by this, the mineral was supposed to be autunite (a hydrous phosphate of uranium and calcium) and an analysis was undertaken. The mineral was scraped off from the rock as carefully as possible and foreign pieces picked out until it seemed to be nearly homogeneous under the lens. In this way, 0.1310 gramme was obtained for analysis, which gave :—

Ignition	13.28
SiO_2	18.55
$(UO_2)_2, Fe_2O_3P_2O_5$	4.95
Al_2O_3	6.33
CaO	6.64
MgO	1.98
$U(UO_4)_2$	47.18
Total	98.91

This result showed that the micas and perhaps some quartz and feldspar from the granite were mixed with the yellow mineral. Another specimen of a dull lemon or sulphur-yellow color was scraped off as before, as carefully as possible and weighed. The weight was 0.5120 gramme. As it was impossible to separate the impurities, the weighed mineral was treated with HNO_3, which left a residue of 0.2460 gramme. 0.2660 gramme was therefore taken for analysis, which gave :—

CaO	6.01
$U(UO_4)_2$	61.28

which with the ignition previously obtained points to unranophane. It was obviously impossible to make any further determination of the SiO_2. The phosphoric acid was found to be *very small* and confined to the uranium-iron precipitate. This mineral blackens before the blow-pipe and in this respect resembles uranophane."

In the hand specimens of the rock, the Stone Mountain granite somewhat resembles certain granites from New Hampshire and Maine; but it is generally found to be more even in texture, and, as Dr. Hawes says, is richer in both quartz and mica. In its appearance, however, it more closely resembles the well known Concord granite of New Hampshire. As already stated, the Stone Mountain granite is remarkably uniform in color, texture and composition, and is entirely free from macroscopic and microscopic blemishes of any character. Free sulphides and oxides of iron are practically unknown in the rock. Somewhat rounded and irregular lighter colored areas, consisting of quartz and feldspar, containing groups of jet-black tourmaline crystals of slender prismatic habit, rarely displaying the terminal planes, are quite common in this rock. As a rule, these areas are usually so small, and otherwise inconspicuous, as to be quite unnoticeable, except upon close inspection. Since this is true, and since tourmaline is practically stable under normal atmospheric conditions, these small groups of radiated crystals do not in anywise injure the stone.

The component minerals, quartz, feldspar and the micas, muscovite and biotite, are readily recognized by the unaided eye. Muscovite greatly predominates over the biotite in the hand specimens.

Microscopically, the rock is a medium-grained, allotriomorphic-granular granite, composed of an aggregate of complexly interlocking quartz and feldspar grains, with numerous grouped plates and shreds of muscovite, and some biotite. The quartz is of the usual granitic kind, irregular in outline, and displays evidence of some stress in wavy extinction and lines of fracture. The feldspar constituent consists of irregular, varying-sized crystals of orthoclase with microperthitic structure; microcline, the larger grains of which show some tendency to tabular habit; and scattered, lath-shaped individuals of polysynthetically twinned plagioclase. The orthoclase usually shows good cleavage, while the microcline exhibits, in a typical degree, the characteristic gridiron or grating structure. The plagioclase individuals give small extinction angles measured on the twinning-plane, in basal sections, which indicates a feldspar near oligoclase. The larger feldspar individuals generally contain rounded drop-like inclusions of quartz and other feldspar species. Muscovite is the predominating accessory present. It occurs, for the most part, as grouped shreds, with good basal cleavage and strong double-refraction, and always appears perfectly fresh. Biotite is more sparingly present as single shreds and filaments, with marked basal cleavage, deep color and strong absorption, partially altered, in some cases, to a reddish-brown chlorite. The biotite shows a tendency to segregate into small bunches, in places. A part of the muscovite is of secondary origin, derived from feldspathic decomposition. Prismatic inclusions of apatite and zircon complete the list of minerals present in the rock.

The chemical composition of this granite is shown in the two following analyses made by Mr. R. L. Packard in the laboratory of the Survey from specimens collected by Prof. Yeates from the Hayne quarry :—

	I	II
Silica	72.56	71.66
Alumina	14.81	16.05
Iron oxide	0.94	0.86
Lime	1.19	1.07
Magnesia	0.20	0.17
Soda	4.94	4.66
Potash	5.30	4.92
Ignition	0.70	1.00
Total	100.64	100.39

I Analysis of the perfectly fresh rock.
II Analysis of a spawl, which was exposed for three or four years on the dump-pile at the quarry.

The above analyses indicate a very acid granite, in which considerable free quartz is present. The alkalies, potash and soda, are present in nearly equal proportions. The rather low percentage of lime and the correspondingly high percentage of soda suggests the presence of both albite and soda-lime feldspars, with the former in excess over the latter. The iron content is somewhat below the normal for granites in general, which would indicate the presence of small amounts of a ferruginous mineral, which in this case is the mica, biotite. This inference is confirmed by the microscope, which shows the principal accessory to be the iron-free mica, muscovite.

Physical tests made on the Stone Mountain granite yielded the following figures :—

Specific Gravity	2.686
Weight of one cubic foot of stone expressed in pounds	167.90
Number of cubic feet of stone contained in one ton (2,000 pounds)	11.9
Percentage (ratio) of absorption	0.067

Crushing strength tests made on the granite, in two-inch cubes, gave the following results :—[1]

	Strength in Pounds	Strength in Pounds per Square Inch
Stone Mountain, Ga.	85,000	21,250
" " "	50,325	12,581
" " "	48,760	12,190
" " "	65,610	16,402

[1] GRANITE PAVEMENTS; compiled by Venable Brothers, Atlanta, Ga.; 1893.

A similar series of strength tests, made in 1890 at Purdue University, Lafayette, Indiana, gave 12,438, 14,425, 12,904, 13,190, 13,406, and 12,726 pounds per square inch.

Another series of tests made on the Stone Mountain granite at the Watertown Arsenal, under the direction of Major J. W. Reilly, U. S. A., gave 25,630 and 28,130 pounds per square inch, on bed.

Freedom from impurities of an unstable character under atmospheric conditions, which at times render a rock liable to discoloration after having been placed in a structure, or further, resulting in a general weakening and, it may be, breaking down of the rock, as a unit, from disintegration or decomposition, gives the Stone Mountain granite a high rank as a general structural stone. Muscovite, the essential accessory mineral present in this granite, is comparatively stable under climatic influences; and the preponderating feldspathic constituent consists of those kinds, which are least subject to change on exposure. Biotite, which is present to some extent in the rock, is the first one of the mineral constituents to yield to external agencies, promoted chiefly through hydration and oxidation of the ferruginous constituent. A careful examination of the granite outcrops in the field indicates, however, that appreciable changes in this mineral only become apparent after a very long lapse of time. The sap (partially weathered rock) on this granite is exceedingly thin, varying from a fraction to several inches in thickness. It consists of perfectly hard and firm rock, colored a pinkish hue from partial decomposition of the biotite. The feldspars are usually very fresh-looking in this portion of the rock, and, when examined microscopically, they show only incipient alteration.

From the nature of the chemical and mineral composition, the character of the natural exposures in the field, and the physical tests given above, this granite is proven to be one of the most durable on the market at present. Its pleasing color, evenness of texture, durability, and easy workability certainly give it the essential qualities requisite to a first-class building material. The excellent finish, which this stone is capable of taking, both polished and hammer-dressed, is well shown in an 8-inch cube on exhibition in the systematic collection of Georgia building stones in the State Museum, in the Capitol Building at Atlanta. The many pieces of beautifully carved granite from this locality, used for ornamental decoration in numerous buildings in the city of Atlanta, add testimony to its superiority of workable character.

The popularity of the Stone Mountain granite through the South and West as a general building and street-paving stone is well shown in the prominent structures, built in part or in whole from this stone, mentioned in the following paragraph: —

Of the many buildings in Atlanta, in which Stone Mountain granite has been used, mention may be made of the Kimball House front and arcade (in part); the Atlanta National Bank building (in part); the Fulton County court-house (in part); the Fulton County court-house annex (front); the Hotel Granite (entire front); the Carnegie Library (entire basement); the new Fulton County jail (entire front and tower); the North Avenue Presbyterian church (entire building); and the U. S. Federal Prison (foundation and 1st story). Outside of Atlanta, some of the principal buildings, in which this stone has been used, for the base course and trimmings are the U. S. Government buildings in Tyler, Texas; Macon, Savannah, Augusta and Atlanta, Ga.; and Louisville, Ky; the City Bank building at Orlando, Fla.; the Home of the Friendless, Chicago; the first story, copings etc., of Dr. W. F. Elkin's house and garden, and Mr. P. A. B. Weidner's sunken garden, at Ogontz, Philadelphia; the entire Sherman monument at Sherman, Texas; and the coping for the Riverside Drive, New York City.

THE QUARRIES OF THE ADJACENT LOWLAND BELT OF GRANITE

As described above, the present dome-shaped mass of granite, Stone Mountain, is flanked on its northern, southern and eastern sides, by a belt of the same rock variable in width, but reduced to the same general level of the surrounding plane, by the usual processes of erosion and denudation. Many of the larger and most favorably located rock exposures in this belt have been worked to some extent.

THE NASH AND McCURDY QUARRY. — This quarry was in process of opening, when field-work on this report was first begun in the early summer of 1898. The rock is exposed in the form of flat surfaces, three miles east of Stone Mountain village, in *lot 85, 18th district*. The quarry was opened for the purpose of furnishing stone for building purposes in St. Louis.

The rock is the same even-textured, light-gray, biotite-bearing muscovite granite, described from Stone Mountain. In addition to the quartz, feldspar and mica, occasional garnets were visible to the naked eye. These were small in size, red in color, and perfectly fresh. In places, the biotite tends to segregate in small bunches and areas.

This property is owned by Messrs. I. N. Nash and J. N. McCurdy, of Stone Mountain, Ga.

THE VEAL QUARRY.—This quarry is a quarter of a mile east of the Nash and McCurdy opening, in the same lot of land; and the two lie across Stone Mountain creek from the Stone Mountain ridge. Some rock was quarried on this property about 1860, and at subsequent intervals, for local purposes in the State. The early quarrying was entirely confined to the surface ledges, averaging two and a half to three feet in thickness. The stone outcrops as flat surfaces, and some half-dozen acres in all have been stripped. The stone quarried in recent years has been used for building and monumental purposes, in this and adjoining States. At the time of the writer's visit, the stone that was being quarried was for shipment to St. Louis for building purposes.

The rock is the same light-gray, biotite-bearing muscovite granite as that quarried at Stone Mountain, and is essentially free from all impurities, such as free oxides and sulphides. Only one vein was visible, which revealed the presence of black tourmaline in a few places. The sap is very thin. The discolored portion is hard and firm rock, of a slight reddish cast, due to the partial decomposition of the biotite; and it varies from a fraction of an inch to several inches in thickness. The rock shows signs, however, of alteration to a depth greater than the discolored portion, manifested in the dullness of appearance due to partial kaolinization of the feldspars. The maximum depth of the weathered zone, including the colored portion, does not exceed, apparently, six to eight, or at most, ten inches. A few small scattered grains of pyrite were observed in several slabs; but this mineral is by no means common.

The large amount of material quarried on this property, some thirty or forty years ago, is shown in the rather extensive openings, and the blocks and spawls of granite left on the quarry-site. Some of this material is in fairly fresh condition; but most of it is in rather an advanced stage of decay, and is discolored from iron derived from the decompositon of the biotite, and rendered soft and friable from kaolinization of the feldspathic constituent. The bulk of this material, if not all of it, undoubtedly represents the long and indefinitely exposed surface layer of the rock.

Microscopically, the rock is allotriomorphic-granular in texture, and is composed of an admixture of interlocking grains of quartz and feldspar, with muscovite and some biotite as the characterizing accessory minerals. The thin section of this rock showed somewhat larger amounts of the microperthitic orthoclase and single polysynthetically twinned plagioclase laths, with a smaller proportion of microcline, than for the average Stone Mountain granite proper.

GEOLOGICAL SURVEY OF GEORGIA
W. S. YEATES
STATE GEOLOGIST
TOPOGRAPHIC MAP OF A PART OF THE
PIEDMONT PLATEAU OF GEORGIA

U.S. GEOLOGICAL SURVEY
CHARLES D. WALCOTT, DIRECTOR.

GEORGIA
ATLANTA SHEET

Henry Gannett, Chief Topographer.
Gilbert Thompson, Geographer in charge.
Triangulation by the U.S. Coast and Geodetic Survey.
Topography by M. Hackett.
Surveyed in 1887-8.

Scale $\frac{1}{125000}$

Contour Interval 50 feet
Datum is mean Sea level

The biotite occurs in somewhat larger and stouter plates, associated with the muscovite, and is considerably altered to chlorite.

An 8-inch cube of granite from the Veal quarry, on exhibition in the systematic collection of Georgia building stones in the State Museum, at the Capitol in Atlanta, well illustrates the excellent finish, both polished and hammer-dressed, the stone is capable of taking. This rock is admirably adapted to the various kinds of structural and street work, for which granite is used.

Microscopic study of a thin section of the reddish colored, partially weathered rock (sap) from the Veal quarry, shows, that the feldspars have suffered but slightly from decomposition, and appear in an almost perfectly fresh condition. The biotite has suffered considerably more than the feldspathic constituent, and is the first mineral in the rock to undergo alteration. The staining derived from the hydration of the ferruginous constituent in the biotite, was distributed not over the surfaces of the individual minerals, but, instead, along the cleavage lines of the feldspars and muscovite; the twinning-planes of the feldspar; the lines of fracture crossing the feldspar and quartz; and along the sutures of the various constituent minerals. The examination of a thin section of the rock, in a more advanced stage of decay, indicated that the iron staining was not entirely confined to the lines of weakness in the minerals, as outlined above; but that it was found discoloring the surrounding mineral areas adjacent to the biotite.

This quarry is owned by Mr. A. B. F. Veal, of Stone Mountain, Ga.

THE THOMPSON QUARRY. — This quarry, which is owned by Mr. R. M. Thompson, of Stone Mountain, is located approximately one mile northeast from Stone Mountain, in *lot 132, 18th district*, and from an eighth to a quarter of a mile east of the Stone Mountain-Centreville public wagon-road. Some rock was quarried on this property, immediately after the Civil War, for local use. In 1897, a second opening, five feet in depth, was made near the old one; but it was abandoned on account of the discoloration of the stone from partial weathering. The outcrop contains some half-dozen acres of exposed flat-surface rock, which, so far as quarrying operations extend, shows that the rock lies in sheets, of varying thickness. The stone is discolored from the surface down to the bottom of the 5-foot opening, by the ferruginous constituent of the biotite. The feldspars are not entirely fresh, but are kaolinized in part.

The rock is a light-gray muscovite granite, containing considerable biotite; and it is slightly coarser-grained than the Stone

Mountain granite. Owing to the partially weathered condition of the rock, so far exposed in the openings on this property, it presents a rather dull appearance, and is somewhat soft and loose-textured (porous). The biotite is apparently the first one of the minerals to yield to the weathering agents.

THE WIGGINS QUARRY. — The property, on which this quarry is located, originally formed a part of the James Howell tract of land. It includes nine acres, purchased by Mr. J. M. Wiggins in 1896. The granite is exposed over nearly the entire nine acres, and is located about a mile north of Redan station on the Georgia railroad, and near the headwaters of Swift creek. The rock is exposed as flat surfaces, over a moderately sloping hillside, down to the stream. The first rock was quarried in 1896. Stone was being quarried, at the time of the writer's visit, for the DeKalb County court-house at Decatur.

The rock is a medium-grained, light-gray muscovite granite containing some biotite. It is hard, fairly close-textured, and lively in appearance. Several small veins were observed, containing crystals of red garnet. No discoloration was apparent, after passing the thin layer of sap; and the stone is in every way well suited for general building purposes.

THE SHEPARD QUARRY. — This property was formerly known as the Hicks place, and was purchased by Mr. James A. Shepard from Mr. Hicks in 1875. The quarry, sometimes called the Hicks quarry, is located in a direct north-and-south line, approximately half-way between Stone Mountain and Redan. The first quarrying was done in 1876. The next work was in 1897, and the stone quarried was used for building purposes. The two openings, which are within close proximity to each other, indicate the removal of only a small amount of stone. The granite is exposed in a number of other places over the property, in the form of flat surfaces.

The rock is a medium-grained, muscovite granite, carrying considerable biotite, which tends to segregate in bunches and small areas through the rock-mass. The biotite shreds are quite variable in size. Veins and slickensided joint-planes are quite common in the openings. The sap is unusually thick in some places, extending to a depth of two feet and more, showing the usual reddish discoloration from the iron staining. A thin section of the partially decomposed rock (sap) indicates, that the ferruginous stain has been distributed over the mineral surfaces, in addition to following the lines of parting, as described in the case of the early weathering in the Veal quarry; and the feldspars are in some cases considerably altered to kaolin and muscovite. The old quarried material, which is still partially firm rock, completely covered with mosses and lichens, is beginning to crumble into a siliceous sand, varying in color, from a light, rusty red to gray, due to the partial decomposition of the biotite and the kaolinization of the feldspar.

THE THOMAS QUARRY.—This quarry is located in *lot 132, 16th district*, approximately six miles southeast from Stone Mountain. The first stone quarried was in 1897, and was used for building and street curbing purposes. Only a small amount of the stone was removed, however. In the spring of 1898, Mr. S. C. Dorby leased the property from Mr. T. L. Thomas, the owner, and began quarrying, for the purpose of supplying stone for the DeKalb County court-house at Decatur.

The rock is not a true massive granite, but, more accurately speaking, a gneissoid granite, of more or less variable grain and texture. In mineral composition and color, it is essentially the same rock, as that quarried at Stone Mountain; but it differs from the latter in being somewhat coarser-grained and containing a larger proportion of biotite. The bulk of the mica present, is the dark-colored variety, which shows strong tendency in some places, to segregate into bands, and more frequently, into bunches, through the rock-mass. The rock is occasionally cut by veins varying from a fraction to several inches in width. The stone is badly discolored to a considerable though variable depth, by a yellowish, ferruginous stain, derived from the ready breaking down of the biotite. The partial decay of this gneissoid granite is quite distinct in a surface zone of approximately one foot in thickness, and consists of dull and opaque kaolinized feldspars and partially decomposed biotite, with the liberation of some ferric oxide. At the immediate surface, and nearly one inch in thickness, the weathered rock is discolored a decided red, as in the case of the Stone Mountain granite. In the more advanced stage of decay, the rock crumbles to a siliceous sand, through hydration and partial decay of the feldspars and biotite. The residual sand is from light gray to reddish brown, the intensity in color of which is conditioned by the stage of biotite decay.

THE CONSTITUTION QUARRY.—This quarry is located on the west side of the Southern railway, about 300 yards west of Constitution station, and six miles south of Atlanta, in *lot 81, 15th district.* The property, consisting of eight acres, was originally owned by Mr. Z. T. Brown, and was sold to THE SOUTHERN GRANITE COMPANY of Atlanta, Ga., in 1890. In the early part of the year 1891, stone was quarried for a monument in memory of the illustrious Henry W. Grady, erected near the Post-office building on Marietta Street in Atlanta. In 1892, a second lot of stone was quarried for a monument to be placed on exhibition at the World's Fair in Chicago. The stone has been used almost entirely for monumental stock; although it has been used for corner stones in several public buildings in Atlanta.

The rock is exposed in ledge form, at the base of a gently sloping hill, just above a small stream. The opening was considerably filled in, by wash from the hillside and stream, at the time of the writer's visit. An 8-inch cube in the systematic collection of Georgia building stones in the State Museum at the Capitol in Atlanta, shows the excellent finish, both polished and hammer-dressed, the stone is capable of taking. It is a very fine-grained and compact muscovite-biotite granite, of uniform texture and light-gray color. A few quartz veins were observed near the top of the opening.

Under the microscope, a thin section of this rock shows an allotriomorphic-granular granite, composed of complexly interlocking grains of quartz, and the potash feldspars, orthoclase and microcline with microperthitic structure; some laths of plagioclase; and muscovite and biotite. The potash feldspars predominate, containing numerous fine, albitic stringers. The orthoclase shows good cleavage and some Carlsbad twinning; while the microcline is readily distinguished from the other mineral constituents, by the characteristic gridiron structure. Plagioclase is sparingly present as lath-shaped crystals, showing well marked, polysynthetically twinned lamellæ. The quartz displays some undulous extinction and lines of fracture, and is further characterized by an abundance of prismatic inclusions of apatite, some of which are bent, curved and broken, the individual parts slipping past each other, as observed in one or two instances. Muscovite is the predominating accessory. It is present as somewhat large and stout, irregular plates. A large part of this mineral is secondarily derived from feldspathic alteration. Biotite occurs as fine shreds, mostly altered to a reddish-brown, opaque chlorite. Occasional intergrowths of quartz and feldspar as micropegmatitic structure occur.

The rock manifests the usual characteristic granite weathering, from hydration and partial decomposition of the biotite and feldspar. As decay advances, from a gray, somewhat rusty-colored, firm rock, it is reduced to a fine-grained, siliceous sand, containing more or less clay derived from the feldspathic constituent.

Approximately 400 yards north and west of the quarry, on the property of Mr. Z. T. Brown, is an outcrop of the same rock in the edge of the woods, to the west of the dirt road, from which some material was quarried by the Southern railway, for culvert construction along its line. The rock is well adapted to monumental purposes and will prove an excellent stone for general construction work.

THE LITHONIA AREA OF CONTORTED GRANITE-GNEISS

In the immediate vicinity of Lithonia and to the north and east, are flat-surface exposures and unreduced residual boss-like masses of a highly contorted biotite granite-gneiss, the latter rising, in some cases, several hundred feet above the surrounding lowland plain. The belt includes the extreme eastern part of DeKalb county, and extends in a northeasterly direction through the northern and middle portions of Rockdale, the western part of Walton, and the southern half of Gwinnett into Jackson county, in the vicinity of Winder.

Megascopically, the rock is a hard and firm, close-textured, fine-grained biotite granite-gneiss. It is prevailingly highly contorted and usually thin banded, the black biotite and light-colored feldspars and quartz being more or less differentiated into layers. The biotite layers are exceedingly thin, when compared with those of the lighter colored minerals. In addition to forming distinct bands, the biotite occurs somewhat regularly distributed through the feldspar and quartz areas.

In some of the quarries over the belt, notably around Lithonia, small crystals of red garnet are abundant, occurring distributed through the rock and sometimes as thick layers of considerable length, alternating with the biotite, quartz and feldspar bands. Large and small grains of magnetite (iron proto-sesquioxide) are very common in this rock. Both segregation and pegmatitic veins occur, in which black tourmaline is alike common. This mineral further occurs in the granite-gneiss as small segregated bunches in well rounded areas of quartz and feldspar, similar to those described in the Stone Mountain granite. The rock-mass is cut by a well defined set of joint-planes, whose surfaces are oftentimes coated with damourite, which is slickensided, grooved and striated, thus affording evidence of subsequent movement.

Microscopically, the gneiss is distinctly allotriomorphic-granular in texture, composed of intricately interlocking grains of quartz and feldspar, with single biotite folia, usually of small dimensions. Quartz and feldspar make up the greater bulk of the rock, while the accessory, biotite, amounts to not more than five per cent. of the whole. The quartz occurs as variable-sized, irregularly bounded grains, showing lines of fracture and undulous extinction, between crossed nicols. The feldspar constituent consists of nearly equal proportions of the potash species, orthoclase and microcline, with microperthitic structure, and a fair sprinkling of plagioclase. Each feldspar species displays its distinctive optical characteristics, and is accordingly readily identified. The proportion of orthoclase to microcline, however, varies considerably in some parts of the belt, first one predominating and then the other, most often, however, the orthoclase. This mineral commonly displays good cleavage, with the spindle-shaped lamellæ of albite clearly and sharply defined. The microcline presents its usual characteristic gridiron structure. These two potash feldspars occur as inequidimensional, allotriomorphic grains, enclosing varying sized, but usually well rounded, drop-like inclusions of quartz and other feldspar species, without optical orientation. The plagioclase individuals occur as somewhat stout, lath-shaped forms, displaying sharp polysynthetically twinned lamellæ, giving maximum extinction-angles, of from 7 to 8 degrees, which probably indicates the feldspar species, oligoclase. Chemical analysis apparently confirms this. The larger quartz and feldspar individuals show some peripheral shattering, and their interspaces are filled with irregular areas of the fine-grained mozaics of the two minerals. Biotite is the predominating accessory, and is present as scattered single folia and shreds, with good basal cleavage, deep color and strong absorption, considerably altered in some cases to chlorite, and associated with some muscovite. Muscovite is present, both as a primary and secondary mineral. In the latter case, it is derived from feldspathic alteration. Some epidote, derived from the feldspar and biotite alterations, occasional garnets, magnetite, and prismatic inclusions of apatite and zircon, complete the list of minerals present.

In chemical and mineral composition, the rock continues remarkably uniform over the entire belt, and is as closely similar in composition to the massive granites, as is possible. The same minerals occur in the two, in practically the same proportions. In chemical composition, the Lithonia belt of granite-gneiss is found to be slightly more acid, containing a larger proportion of free quartz, than the average massive granite; and is slightly lower in the alumina, iron and lime contents; but they are practically equal in the percentage of alkalies. It will be observed, further, that the alkalies, soda and potash, are present in nearly equal proportions, which is also true of both the granites and their accompanying porphyritic facies. The following table of analyses of the contorted granite-gneiss from the various counties over the belt serves to illustrate the uniformity in rock composition: —

	DeKalb	Gwinnett	Rockdale	DeKalb	DeKalb
SiO_2 . . .	76.00	75.89	75.45	75.16	72.96
Al_2O_3 . .	13.11	14.02	13.71	13.74	14.70
Fe_2O_3 . .	0.92	0.71	0.92	0.91	1.28
CaO . . .	1.06	0.70	0.94	0.91	1.28
MgO . . .	0.27	0.12	0.18	0.17	0.07
Na_2O . .	3.88	3.64	3.87	3.76	4.18
K_2O . . .	4.69	5.56	4.30	5.02	4.73
Ignition . .	0.31	0.28	0.40	0.32	0.23
Total . .	100.24	100.92	99.77	99.99	99.43

The outcrops of contorted gneiss in the various counties are everywhere surrounded by a thinly foliated mica-schist. No contact between the fresh gneiss and the perfectly fresh mica-schist was anywhere visible; but abundant contacts of decayed material of the two rocks were observed, and in each case, showed marked differentiation with no intermediate gradations.

From the analogous mineral and chemical composition and the microscopic affinities to the massive granites; the form and manner of weathering; the occurrence of segregation and pegmatitic veins; and the field relations to the surrounding country-rock, the Lithonia belt of contorted gneiss is believed, by the writer, to be a highly metamorphosed gneiss, derived from an eruptive granite mass, older in age, than the adjacent massive granites. Hence, these gneisses are referred to as granite-gneisses.

Description of the Individual Quarries

Numerous quarries have been opened in each of the above named counties in the gneissic belt, and a large amount of stone has been worked into Belgian blocks, slabs and curbing, and shipped to the principal cities in the South and West for general street paving. A good proportion of the rock, however, has been further used for building and other construction work in this State. The Lithonia section in DeKalb county was the first part of the belt to be worked; and extensive developments have been made and large amounts of the rock, quarried and shipped. The rock possesses all the essential qualities of a superior stone for street purposes. Owing to the readiness and ease, with which it is quarried and worked into shape, and the abundance and cheapness of labor, the entire area is unsurpassed in this country, for supplying unlimited quantities of excellent stone for paving and general street work.

THE ROCK CHAPEL MOUNTAIN QUARRIES.—This residual mass, mountain so-called, from its higher elevation above the surrounding plane, contains 110 acres in all, and is located in the *16th district*, six and a half miles southeast from Stone Mountain, and three miles northeast from Lithonia. Eighty-five acres, including the west and northwest sides, are owned by Hon. Hoke Smith, of Atlanta; and the remaining 25 acres, along the east and southeast sides, are owned by Messrs. Lee Brothers, of DeKalb county. Messrs. Venable Brothers, of Atlanta, control a narrow strip lying along the base of the southeastern edge. This area forms one of the numerous dome-shaped masses in the region, and is roughly circular in outline, with the two diameters approximately the same. It is almost completely encircled at its base by small streams, which lie in rather deep and broad, carved alleys. A good illustration of this is found on the north and northwest sides, where an escarpment of the granite-gneiss, facing mountainward, has been eroded by one of the streams, and stands out conspicuously with an apparent dip and slope away from the peak. The same condition is more or less continuous, though by no means so conspicuous, along and near the base of other portions of the peak. These serve to illustrate the part, stream erosion has played, in the shaping of this and other similar residual masses in this region.

Some 14 quarries have been raised over the entire boss; but, with one single exception, the West-side quarry, no stone has been removed. The raised quarries extend from the top down to the base of the north and northwest sides. The stone is a highly contorted biotite granite-gneiss, as described above, and is well suited for general street work.

The sap (partially decayed rock) is very thin, and consists of the usual hard and firm, reddish colored material. Two branch railroads leading to this property have recently been surveyed. One of them is from Tucker, a station on the Seaboard Air Line railway, to Lithonia, a distance of 14 miles. It was surveyed about seven years ago. The second one was surveyed about three years ago, from Redan station on the Georgia railroad to the above property, a distance of approximately four miles. Good and easy grades are obtainable in either case at a minimum cost. With the exception of a few scattered, stunted cedars and some mosses and lichens, the peak is entirely free from vegetation.

THE JAKE CHUPP QUARRY.—This property is located on *lot 91*, *16th district*. It can hardly be considered a true quarry; for it is

A GRANITE CRUSHER AT LITHONIA, GEORGIA, USED FOR CONVERTING THE QUARRY WASTE INTO ROAD METAL AND BALLAST.

more in the nature of a very small opening. The opening was recently made in one of the boulder outcrops on the west side of the Lithonia-Rockbridge wagon-road, from a half to three quarters of a mile northwest of Rock Chapel Mountain, to obtain rock for local use. The rock, so far as opened, is an excellent grade of the contorted biotite granite-gneiss, described above.

This property is owned by Mr. Jake Chupp, of Lithonia, Ga.

THE LEE BROTHERS QUARRIES. — This property comprises some 150 acres of exposed granite-gneiss, located less than one mile from Rock Chapel Mountain, and owned by Messrs. Lee Bros., of Lithonia, Ga. It includes 75 acres of continuously exposed flat-surface rock, lying adjacent to, but cut off from, Rock Chapel Mountain by means of stream erosion. Three or four surface "raises" have been made, from time to time, in different places over the property, for the purpose of getting some stone for local use, and to test its quality. Practically no work has been done, however. The first opening was made nearly 40 years ago, and that portion of the stone left as large blocks is badly discolored by the hydration and oxidation of the ferruginous constituent, derived from the partial decomposition of the biotite. The feldspars are in an advanced stage of kaolinization, and the rock is rendered soft and friable, and is easily reduced to a rusty colored, siliceous sand. None of the openings are of recent date.

Immediately south of, and separated from, the Lee Brothers property by a deep gulch, are some 30 acres of similarly exposed rock, owned by Mrs. Matilda Ragsdale. No work has been done on this property.

THE FLOYD QUARRY. — This property is located on *lot 94, 16th district*, a quarter of a mile from Redan station, and on the west side of the Redan public wagon-road. The quarry was opened in 1885, and the rock quarried was used for foundation stone in the Custom-House building in Atlanta. A royalty was paid the owner, Mr. John H. Floyd, of Redan, by the lessees, on all stone quarried. The property is owned at present by Messrs. Venable Bros., of Atlanta, and others.

The rock is a rather coarse-banded granite-gneiss, of light-gray color, and is only slightly contorted. It is quite irregular in grain and structure; very badly cut up by veins; and is suited only for rough work.

A small opening has been made in an extensive outcrop of the same rock, 350 yards from the quarry, on the east side of the wagon-road. No stone has been removed from this opening.

THE WILSON QUARRY.[1] — This quarry is located on *lot 133, 16th district*, 2 1-2 miles northeast of Lithonia, and five miles southeast of Stone Mountain. The property includes 70 acres, originally owned by Mr. James R. Wilson, over most of which granite-gneiss outcrops as flat surfaces. Several surface "ledges" were worked for cemetery stone, prior to Mr. Wilson's ownership. The first systematic work was begun, however, in 1891. In 1898, Messrs. Watson & Brantley of Lithonia, and Mrs. Bowe, of the same place, purchased the entire seventy acres, each controlling a half interest. Work was immediately begun by Watson & Brantley, and has been continued up to the present, averaging about 30 hands per day. Five openings within close proximity to each other, have been worked, most of which are quite extensive, indicating a large amount of stone quarried. One hundred and fifty car-loads of rock were removed between February and August of 1898. A branch road extending from No. 8 siding of the Georgia railroad, 1 1-2 miles north of Lithonia, has been completed to the quarry, a distance of two miles.

The rock is the typical contorted Lithonia granite-gneiss, of excellent quality. The partially decayed rock (sap) is very thin, and usually of a reddish color, due to the ferruginous stain derived from the partial biotite decay. A considerable sprinkling of large magnetite grains occurs through the rock, but no staining, apparently, has resulted from this mineral. The rock is admirably adapted to all kinds of paving and general street work.

THE WHITLEY QUARRY. — The Whitley quarry lies a quarter of a mile southwest of the Wilson quarry, and half-a-mile east of the Thomas quarry, in *lot 132, 16th district*. Six openings, almost joining each other, have been made on this property, only one of which was being worked at the time of the writer's visit. The entire property includes 201 acres, with approximately 20 acres of flat-surface rock exposures, in which the openings have been made. Other outcrops of the same rock, of smaller dimensions, occur in places over the property; but they have not been worked. Less than a dozen hands were employed by the owner, Mr. Needham Whitley, in quarrying the rock for Messrs. Watson & Brantley, to be used as paving and curbing material.

The rock is an excellent quality of the Lithonia contorted granite-gneiss, described above. The sap of this rock averages approximately the same in thickness as that observed in quarries of the similar rock in this section. The usual sprinkling of magnetite occurs; and some jointing and veins, cutting the rock-mass, were present.

[1] Also known as the Watson & Brantley Quarry.

A part of the stone from this quarry was used in the Second Presbyterian Church and the buildings of Mercer University, in Macon, Ga.

THE BOSIER QUARRY. — This quarry is located on *lot 155, 16th district*, near the Bosier dwelling-house, and several hundred yards away from, and on the east side of, the Lithonia-Stone Mountain wagon-road. The rock outcrops as flat surfaces over the greater portion of the entire tract of 52 acres. In 1890, the Lithonia Co-operative Granite Company leased the property from Mr. T. A. Bosier, and immediately began quarrying, which was continued for ten months. The stone quarried was used exclusively for Belgian blocks, of which there were 100,000 produced and sold to Mr. John H. Bradley, of Atlanta. In 1898, a second lot of stone was quarried for curbing.

The rock is the same light-gray, fine-banded, highly-contorted biotite granite-gneiss as that quarried at Lithonia. It contains large disseminated grains of magnetite and occasional small areas of grouped tourmaline crystals. It is of excellent quality, and is well suited for general street work.

THE WEEKS QUARRY. — This quarry is located on *lot 156, 16th district*, a quarter of a mile northeast from the Bosier quarry. The property contains 113 acres, with flat-surface outcrops of the contorted granite-gneiss in the southeast and southwest corners. In the fall of 1897, one quarry was opened under a lease for one year, for the purpose of quarrying Belgian blocks. The rock is the same as that quarried at Lithonia; and, so far as it is exposed by working, it is apparently of good quality. It is owned by Mr. John W. Weeks, of Lithonia.

THE DUNCAN QUARRY. — This property is located on *lot 165, 16th district*, half-a-mile northeast of the Bosier quarry, and one and a half miles north of Lithonia. The property contains 50 acres, with probably a half-dozen acres of exposed rock, and is owned by Mr. R. S. Duncan, of Lithonia. In the fall of 1896, two openings were made in close proximity to each other, and some stone was quarried for blocks and curbing. The rock is a good grade of contorted biotite granite-gneiss, and is thoroughly suited for street purposes. Small and scattered bunches of black tourmaline crystals were observed in places through the rock-mass.

A second opening was made by Mr. Duncan in an outcrop of the same rock, less uniform in grain and structure, on *lot 187, 16th district*. No rock was shipped from this opening.

THE JOHNSON QUARRY.—This property contains six acres lying half-a-mile north of Little Pine mountain. It forms a part of the lowland plane adjacent to, but separated from, Little Pine mountain by erosion. The first quarrying was done in 1886, and the stone was worked into blocks, curbing and flagging. Work has been more or less continuous from the beginning, in 1886, to the present time. The quarry is a very extensive one, indicating considerable work done, and a large amount of the stone quarried.

The rock is an excellent grade of contorted granite-gneiss, carrying, in some places, large quantities of small red garnets in layers, and also, irregularly distributed through the black biotite and lighter-colored quartz and feldspar bands. Some magnetite and black tourmaline crystals are disseminated through the rock. The quarry was again leased in September, 1898, by Mr. John McArthur, of Lithonia, and work was resumed.

This property is owned by Mr. G. W. Johnson, of Lithonia.

THE J. H. CHUPP QUARRY.—This property is located on *lot 186, 16th district*, 200 yards west of the Johnson quarry on the south side of the wagon-road, and to the southeast of the Duncan quarry, and is owned by Mr. J. H. Chupp, of Lithonia. The property was leased about seven years ago, when the first work was done. It was again leased in 1896 and in 1897. Only a small amount of work has been done, and this was confined entirely to the top ledge. The stone quarried was used for blocks and curbing. The rock contains the usual quantity of magnetite, and is considerably discolored from the partial decay of this mineral and biotite.

THE GODDARD QUARRY.—This quarry is located on *lot 186, 16th district*, about fifty paces from the Chupp quarry. These two quarries are in the same outcrop of flat-surface granite-gneiss, three or four acres of which are exposed. The Goddard opening, which is very small, has furnished only one carload of rock. As in the case of the Chupp quarry, only the surface layer of the Goddard rock has been worked. This portion of the rock is badly discolored from ferruginous stains derived from the decomposition of magnetite and biotite.

Mr. James Goddard, of Lithonia, is the owner of this property.

THE COLLINSVILLE MOUNTAIN QUARRIES.—Collinsville Mountain forms one of the smaller, dome-shaped residual masses of contorted granite-gneiss, and is located approximately one mile to the south and east of Lithonia, and immediately south of, and adjacent to, Little Pine mountain. The doming mass rises 75 to

100 feet above the surrounding plane, with moderate slopes and rough and uneven surface. It has been cut off from Little Pine mountain by means of erosion. A broad valley, from a quarter to half-a-mile in width, connects the two residual masses, showing more or less continuous exposures of the hard and firm granite-gneiss over its entire bottom. The main line of the Georgia railroad passes directly over the southern slope of the mountain. Two average size quarries have been worked in that portion of the basal slope, cut off by and lying on the south side of the railroad. The northwestern slope forms a part of the valley between this and Little Pine mountain, the correlative portion of which, is the south and southeast margins of the latter mountain. The surface layers have been raised and worked over nearly the entire rock-mass. No work was being done at the time of the writer's visit.[1] This property is owned at present by the "Southern Granite Company," the general manager of which is Mr. F. B. Glenn, of Atlanta.

The rock is a light-gray, irregularly banded, contorted biotite granite-gneiss, highly garnetiferous in places. The garnets are frequently of large size, and are partially altered to a brownish-colored epidote with distinct resinous lustre. Crystals of magnetite and black tourmaline are distributed through the rock in the usual quantity. The surface portions of the rock are colored from ferruginous staining, derived from the partial decay of the biotite and magnetite. The feldspars are dull and opaque in appearance from partial kaolinization. A large amount of the stone has been quarried and shipped to various sections in the South, for paving and general street work.

THE CROSSLEY QUARRY.—This property includes forty acres of exposed rock, located three and a half miles southeast from Lithonia and occupying the lower basal portion of the western slope of Arabia mountain, cut off by means of stream erosion. It lies directly on the west side of the Lithonia-Rockdale wagon-road. This road lies in turn along the shallow stream-valley crossing the above property. The slope on the west side of the road is very gentle, making an angle of only a few degrees. The first stone was quarried about ten years ago. Some six openings in all have been worked, and a large amount of stone has been quarried. Only one of these, however, was being worked, at the time of the writer's visit in September, 1898. The stone quarried

[1] A visit by the writer to this property, during the summer of 1901, indicated that work had been resumed on rather an extensive scale. The stone quarried was being worked into curbing, to supply orders from Washington, D. C., and St. Louis. Messrs. Bishop & Sons, of Lithonia, were operating a crushing-plant on the property, in order to utilize the quarry-waste.

was used almost exclusively for street purposes, it being shipped to St. Louis, Birmingham and Montgomery, and the principal towns in Georgia.

Messrs. Venable Brothers own the extreme southern and northern portions of this slope, and one quarry has been worked on the southern, and several on the northern portion, by them. Mr. J W. Crossley, of Lithonia, owns the remainder.

The rock is a light-gray, highly contorted, biotite granite-gneiss, of irregular banding. Joint planes, whose surfaces have been slickensided, and are coated with damourite, a variety of muscovite, somewhat grooved and striated, indicating subsequent movement, are frequently found cutting the rock-mass. Segregation veins, of slight dimensions, are somewhat common in the rock. Garnets, forming layers, and also distributed through the other mineral areas, with scattered groups of tourmaline crystals, are quite abundant.

The following analyses made by the writer, in the Survey laboratory, illustrate the chemical composition of the fresh and the partially decayed rock from this quarry : —

	I	II	III
Silica	76.00	73.48	71.67
Alumina	13.11	14.78	16.14
Iron Sesqui-oxide	0.92	1.30	1 22
Lime	1.06	0.31	0.29
Magnesia	0.27	trace	0.10
Soda	3.88	3.43	2 80
Potash	4.69	5.00	4.52
Ignition	0.31	2 42	4.03
Total	100.24	100.72	100.77

I Analysis of fresh contorted biotite-gneiss.
II and III Analyses of the same rock, partially decayed.

A full discussion of the manner and changes in the weathering of this rock is given in Chapter V, Part 2, of this report.

THE WADE QUARRY. — This quarry is located in the southeast corner of *lot 108*, *16th district*, approximately three quarters of a mile north from the Crossley quarry. The property includes 112 acres of land with about five acres of exposed rock, in which the quarry is located. A second outcrop of the same rock containing three acres occurs in the southwest corner of *lot 117, 16th district;* but it has never been worked. The above quarry was opened by Mr. Wade about 12 years ago; but only a small amount of the rock has been quarried. It is an excellent grade of contorted granite-gneiss, free from discoloration, but very irregular in banding. Small segregated areas, of a more basic character, carrying more biotite and darker in color than the enclosing gneiss, occur in the rock. Slickensided joint planes, of the same nature as those described in the Crossley quarry, and veins of segregation were observed in this rock. No work was being done at the time of the writer's visit.

The property is owned by Mr. T. T. Wade, of Lithonia.

THE JENKINS QUARRY. — This quarry is located on the property of Mr. J. G. Jenkins, half a mile north of the north peak of Arabia mountain, with the public wagon-road passing directly over the main rock exposure. Three to four acres of flat-surface rock are exposed, in which three openings were made some years ago. The work was apparently confined to the surface layer, and but little rock was removed. This rock exposure represents a part of the lowland plane adjacent to the north Arabia mountain peak, with the intervening portion covered with a light-gray granitic soil. The rock is badly discolored from ferruginous stain derived from the partial decay of the iron-bearing minerals present. Some veins of segregation, and occasional garnets, here and there, occur in the rock. It is an irregularly banded, light-gray, contorted biotite granite-gneiss, of good quality.

Mr. Jenkins owns some half-dozen acres of exposed rock, situated immediately on the south side of the public wagon-road, and about a quarter of a mile west of Cooper's quarry. One opening has been worked at this exposure, and a fair amount of stone has been taken out. The rock outcrops in the form of horizontal sheets. So far as quarrying operations have extended, the rock is a good grade of contorted biotite granite-gneiss. It is irregularly banded, light-gray in color, and slightly discolored from ferruginous stain derived from the partial decay of the iron-bearing minerals present.

A third quarry owned by Mr. Jenkins is located a few paces south of the Cooper quarry in the same rock outcrop. A considerable amount of stone has been quarried from this opening, which is the same rock as the Cooper rock, a description of which is given below.

THE COOPER QUARRY. — This quarry is located about the center of the west half of *lot 173, 16th district*, approximately one mile northwest of the north peak of Arabia mountain, and two and a half miles south of Lithonia, on the south side of the wagon-road immediately opposite Mr. Cooper's dwelling-house. Several openings have been made in the eight-acre exposure of the flat-surface-rock outcrop, and a considerable amount of the rock has been quarried.

The rock is an excellent grade of the Lithonia contorted granite-gneiss, slightly discolored and carrying a somewhat larger amount of biotite than usual in the same rock of the adjacent quarries. Some segregation veins and areas of tourmaline crystals are found in places in the rock.

A second outcrop of this rock occurs in the south corner of the same lot; but it has never been worked.

Mr. D. B. Cooper, of Lithonia, owns the property.

THE HENDERSON QUARRY.—The work on this property consists of a slight surface stripping, made some years ago in an outcrop, of less than two acres in extent. No stone has ever been shipped. The property is said to be owned at present by Mr. Lawson Smith, of Lithonia, and is located a few miles from Lithonia on the east side of the public wagon-road. The rock is the same as the Lithonia contorted granite-gneiss.

THE BRANTLEY QUARRY.—This property consists of several acres of a flat-surface-rock outcrop, occurring on both sides of the Lithonia public wagon-road, where the railroad, leading to Arabia mountain, crosses the wagon-road. Most of the outcrop, however, is on the east side of the wagon-road, in which the opening has been made.

The rock is a light-gray, contorted biotite granite-gneiss, carrying some magnetite crystals and displaying the usual discoloration from iron stain. Some of the spawls, quarried years ago and left near the opening, offer splendid opportunity for studying the condition of weathering of this rock. The feldspars are in an advanced stage of kaolinization; and, while the spawls are for the most part intact, they have begun to crumble into a light-gray siliceous sand, more or less stained from the iron derived from the partial decay of the biotite. The spawls commonly admit of easy crumbling under pressure in the hand.

Mr. Lee G. Brantley, of Lithonia, is the owner of this quarry.

THE ARABIA MOUNTAIN QUARRIES.—Arabia mountain consists of two large dome-shaped residual masses, or peaks, averaging from 75 to 100 feet in elevation, and separated by a rather broad valley. The peaks have a northeast-southwest alignment. Their western slope is a gentle one, partly dissected near its basal portion by a broad and shallow valley, occupied at present, by a small stream, along which the Lithonia public wagon-road has been graded. The southwest peak is the higher and larger of the two. A stunted growth of scattered trees, belonging to the pine family, occurs in places over the peaks, and the entire rock-surface is pre-

Fig. 1

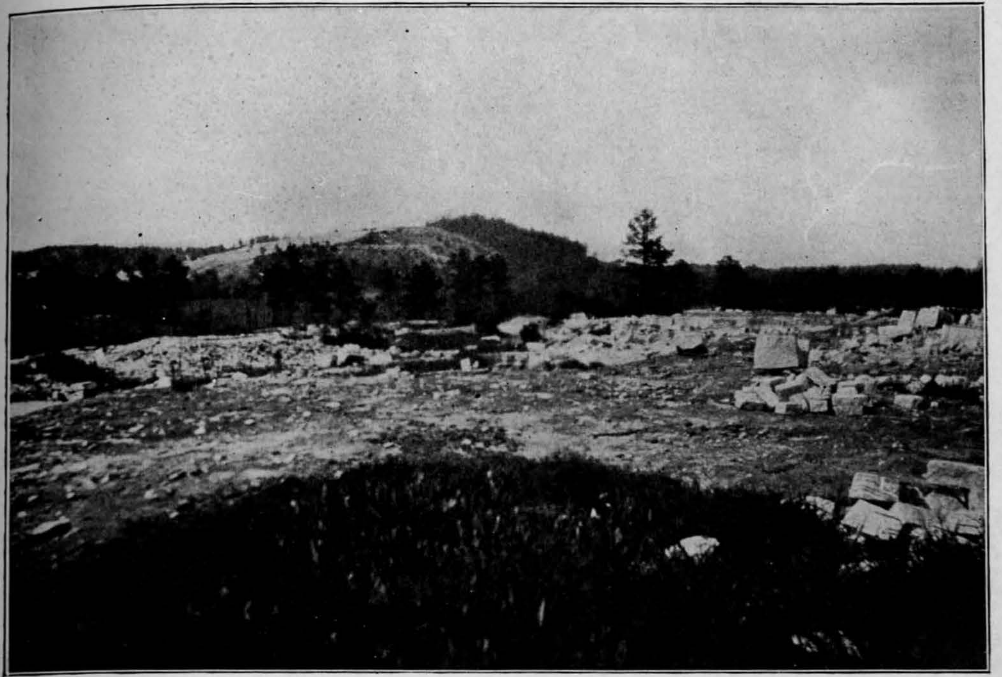


Fig. 2

GRANITE-GNEISS QUARRIES IN THE LITHONIA AREA.

Fig. 1. A General View from Collinsville Mountain to Pine Mountain in the Background, the White Area on the Latter Showing the Location of Its Extensive Quarries. In the Foreground, is a Flat-surface Quarry.

Fig. 2. A General View of the Arabia Mountain Quarries.

vailingly covered with mosses and lichens. Hard and firm rock is exposed in the bottom of the valley separating the peaks, and in the valley separating the basal part of the western erosion slope from the peaks. With the exception of five or six acres located on the northeast side of the northeast peak, owned by Messrs. W. R. Watson and L. G. Brantley, of Lithonia, the entire peaks are owned by Messrs. Venable Brothers, of Atlanta. This property is located three miles south of Lithonia, from which a branch railroad is in operation from the Georgia railroad to the northeast peak of the mountain. Not less than a dozen quarries, of large dimensions, have been worked over the entire basal slope and edges of the northeast peak, less extensively, however, on its eastern side. Development has not been so extensive on the southwest peak; but the stone has been raised over approximately half of its slope. The quarries are confined to the northeast, north, northwest and west sides. Preparatory to opening quarries, the stone has been raised over nearly the entire eastern portion of the southwest peak; but no stone has been removed. The south and southwest sides have not been touched at all.

The rock is a hard and firm, medium-grained, highly contorted biotite granite-gneiss. It is irregularly banded, and light-gray in color. Segregation veins, garnets, areas of tourmaline crystals and some magnetite are present in the rock. Their distribution, however, is very irregular. Slickensided joint-planes, coated in some cases with a light-greenish to white damourite, indicating considerable movement in the rock-mass, are found cutting the rock. As would be expected, the rock is somewhat variable in structure; but it is an excellent grade of granite-gneiss, thoroughly adapted to general street work.

Generally, small masses of rock are found over the surface of the peak in an advanced stage of decay. These are usually intact; though they crumble readily under pressure of the hand. The partially decayed product varies from a light-gray to red in color, according to the degree of decay of the iron-bearing minerals. The residual product is readily reduced to an admixture of kaolinized feldspar and quartz with scattered mica folia.

To the north, northeast and northwest of the Arabia peaks, somewhat continuous outcrops of the same rock, extending for several miles, have been reduced to the same general level of the surrounding lowland plane.

The following analysis, made by the writer in the laboratory of the Survey, on specimens of the fresh rock, shows the chemical composition of the Arabia Mountain granite-gneiss: —

Silica, SiO_2	75.16
Alumina, Al_2O_3	13.74
Iron Sesqui-oxide, Fe_2O_3	0.91
Lime, CaO	0.91
Magnesia, MgO	0.17
Soda, Na_2O	3.76
Potash, K_2O	5.05
Ignition	0.32
Total	100.02

The percentage (ratio) of absorption for this rock is 0.050.

To the southeast of Arabia mountain, is a second large residual boss-like mass of contorted granite-gneiss, cut off from the above by erosion. It is owned by Messrs. J. W. Kelly and William Terry, of Lithonia. The former owns the northeast side, and the latter, the southwest part of this peak. Several quarries have been raised; but no stone has been quarried on the property.

THE WALKER QUARRY. — This quarry is located one and a half miles southeast from Lithonia, and is owned by Mr. G. W. Walker, of that village. The property contains thirty-one and a fraction acres, twelve to fourteen acres of which is exposed rock. The rock was formerly owned by Mr. M. E. Maher, of Atlanta, and the first work was done in 1890. Work was again resumed late in the summer of 1898, and the rock quarried was used principally for street purposes.

The rock is an irregularly banded, light-gray contorted biotite granite-gneiss, carrying some magnetite, and cut in places by segregation veins.

A second opening in the same rock has been made near the top of the hill, 200 yards south of the main quarry; but very little stone has been quarried.

THE JOHNSON QUARRY. — This property, owned by Mr. J. C. Johnson, of Lithonia, is located one mile south of Lithonia, and includes half-a-dozen or more acres of exposed flat-surface rock, in which two openings have been made several hundred yards apart. One of these has been worked quite extensively, and a large amount of the rock has been quarried. The second one scarcely amounts to more than an opening, indicating but little quarried rock. This rock is an excellent grade of the Lithonia contorted granite-gneiss.

THE J. L. CHUPP QUARRIES. — This property contains ten acres of flat-surface-rock outcrop, located on *lot 154, 16th district*, in which six large openings have been made. The most northerly quarry is five-eighths of a mile from Lithonia, near the north line of the lot, with the remaining ones extending in a south line passing through the central part of the lot, and having a north-south alignment. This property joins the Southern Granite Company's quarry, the two being in the same rock. One quarry, opened in a two-acre outcrop, located in the south-central part of *lot 167, 16th district*, was being worked. It is a most excellent grade of stone. Work was first begun in 1882 on *lot 154*, and has been more or less continuous up to the present. The quarries have always been worked under lease from Mr. J. L. Chupp, of Lithonia, with a royalty paid on all rock quarried. Mr. W. A. Evans was working one quarry on *lot 154*, and Messrs. E. O. Reagin & Co., three in the same lot, and one in *lot 167*, under lease from Mr. Chupp, at the time of the writer's visit. An approximate estimate shows, that about 50,000 feet of stone has been quarried on this property per year, for the past ten years. The stone quarried has been shipped to a number of cities in and outside of the State, and used principally for street purposes and to some extent in building.

The rock is a light-gray, contorted biotite granite-gneiss, of excellent quality, carrying a few layers of garnets, and cut in places by pegmatitic veins.

THE BRASWELL QUARRY. — Only a few feet of stone have been quarried from a small ledge outcrop, 400 yards southwest from the Chupp quarry on lot 167. The rock outcrop is located near the northern part of *lot 158, 16th district.* The surface portion of the rock is highly discolored.

This quarry is owned by Mrs. Avy Braswell, of Lithonia.

THE BRAND QUARRY. — This property is located in the northeast corner of *lot 169, 16th district.* Approximately 20 acres of exposed rock occur, in which eight quarries have been worked, only two of which were working at the time of the writer's visit. The property is located near the Georgia railroad, almost between Little Pine and Collinsville mountains, occupying the southwest side of the former and the northwest side of the latter, and cut off from the two by erosion. The openings are quite extensive, and a large amount of the rock has been quarried. This has been used mostly for street purposes.

It is an excellent grade of light-gray contorted biotite granite-gneiss, containing some layers of garnet and the usual sprinkling of magnetite grains.

Mr. J. T. Brand, of Lithonia, is the owner of this property.

THE MARY REAGIN AND GEORGIA RAILROAD QUARRY. — This quarry is located within a few paces of the DeKalb-Rockdale county-line, immediately on the Georgia railroad, and about two miles east from Lithonia. The rock outcrops in the form of horizontal sheets, and is the same contorted biotite granite-gneiss as that quarried at Lithonia. Considerable quarrying has been done, and a good quantity of the rock, removed, confined apparently to the surface raise.

This quarry is owned jointly by Mrs. Mary Reagin, of Lithonia, and the Georgia Railroad Company.

THE SOUTHERN GRANITE COMPANY'S QUARRY. — This quarry is located on *lots 154 and 155, 16th district*, three quarters of a mile north from Lithonia. The quarry opening extends over some four or five acres, reaching a depth in many places of 15 to 20 feet, and furnishing at least four separate raises in superposition. An unusual quantity of rock has been quarried for blocks and curbing, and shipped to the principal towns in the South. Only a little work was being done at the time of the writer's visit.

The rock is an excellent grade of fine and quite uniformly banded contorted biotite granite-gneiss. It is entirely free from discoloration, except a few inches of the surface portion. A considerable sprinkling of magnetite grains, and several small areas of molybdenite occur through the rock-mass.

The following analyses of the fresh (I) and partially decayed (II) rock, made by the writer in the laboratory of the Survey, on specimens of rock collected from this quarry, serve to illustrate the chemical composition of the rock: —

	I	II
Silica	72.96	74.53
Alumina	14.70	13.70
Iron Sesqui-oxide	1.28	1.15
Lime	1.28	0.95
Magnesia	0.07	trace
Soda	4.18	4.41
Potash	4.73	5.20
Ignition	0.23	0.81
Total	99.43	100.75

This property is owned by the Southern Granite Company, of Atlanta.

THE GEORGIA RAILROAD QUARRY.—This quarry is located near the southeast corporate limits of the town of Lithonia, and is owned by the Georgia Railroad Company. The rock is exposed as flat surfaces with most of the surface stripped and worked to some depth. The quarry was worked for several years under lease by Messrs. Phillips & Bishop, of Lithonia, who still retain the leases, but are working separately different parts of the outcrop.

A large amount of the rock has been quarried and worked into blocks and curbing for street paving, and shipped to various points in Alabama, Florida, Georgia and Tennessee, with small shipments to Chicago and Washington, D. C.

The rock is an excellent grade of the irregular banded contorted biotite granite-gneiss admirably suited for the purposes for which it is used.

Messrs. Bishop & Sons operate two crushers in the Lithonia area, which utilize the granite waste from quarrying by crushing it to a uniform sized gravel, which is used for railroad ballast and for macadamizing roads and streets. At present, there are four crushers in constant operation in the Lithonia granite-gneiss area. Most of the rock crushed is furnished under contract to the railroads for ballast.

PINE MOUNTAIN AND ITS QUARRIES.—Pine Mountain, so-called locally, but designated as Little Stone Mountain on the Atlanta topographic sheet of the United States Geological Survey, is the largest one of the single dome-shaped masses of granite-gneiss occurring in the Lithonia area. Placing the average elevation of the Piedmont plain in this locality at 1,000 feet above mean sea-level, Pine Mountain rises 125 to 150 feet above the general level of the plain. Like Stone Mountain and other smaller though similar areas of hard granitic rock in this section, Pine Mountain represents an unreduced residual, rising above the general level of the surrounding lowland plain.

It is owned by Messrs. Venable Brothers, of Atlanta, and is located one mile east of the village of Lithonia, with an elevation of 150 feet above the track of the Georgia railroad in front of the depot at Lithonia. Its slopes are well rounded and have easy gradients, and for the most part are bare of the larger forms of vegetal growth, although some of its parts are rather thickly set in a growth of pine interspersed with scattered oaks and cedars.

As a rule, the surface rock of the dome-shaped mass is perfectly hard and almost entirely fresh, manifesting only slight indications of any appreciable decay. Only here and there, do small areas of the disintegrated and decomposed rock appear, sufficient to form a scant soil, in which plant life may be sustained.

In topographic outline and other characteristic features of form, Pine Mountain somewhat closely simulates certain topographic types, common to glaciated lands, as do the other mentioned dome-shaped masses of the hard granitic rock in this locality.

The rock is a typical contorted biotite granite-gneiss, composed of a granular admixture of feldspar, quartz and biotite with scattered folia of muscovite. Under the microscope, the component minerals are seen to interlock in an intricate manner, imparting thereby great strength to the stone. The general absence of visible jointing in this mass, usually common to granite areas, is a very noticeable feature. Occasional segregation veins, of slight dimensions, and small segregated areas of biotite and feldspar are observed. Scattered grains of magnetite, garnet and rarely tourmaline areas, similar to those occurring in the Stone Mountain granite, have been seen in places.

The rock is admirably adapted to all kinds of street work, for which it has been extensively used in the form of both Belgian blocks and curbing. The waste rock from quarrying is put through a "crusher", which can be regulated to yield rock fragments of any size desired. The crushed rock is used for ballast for railroads, and for the construction of Macadam roads. This rock has proved highly satisfactory for both purposes. Two plants for crushing the waste rock are in operation on this property.

Pine Mountain was the first property to be opened and systematically worked in the Lithonia area. It was first worked in 1883, and its quarries are among the largest and most productive in this section. Vast quantities of the stone have been quarried and shipped to all parts of the South and Middle West. Indeed, it is stated, that stone from these quarries has been shipped to all the principal towns and cities in the South and West for street work. The equipment is extensive and thorough, which insures the handling of stone of almost any dimension and the prompt filling of large orders. The equipment with the ready labor at hand makes it possible to speedily raise the quarries to their maximum output. Mr. W. H. Venable informed the writer, that, at one time, as many as thirty car-loads of the rock per day were shipped from these quarries. The ease with which the rock can be quarried is a noteworthy feature, as well as a most important one, from an economic standpoint. Beginning at the bottom of the slope, one raise, ranging from seven to eleven feet in thickness, is readily effected, extending nearly or quite to the top, and having nearly proportional width. A track is operated from the main line of the Georgia railroad at Lithonia to the quarries. For the past six months, the output from these quarries has been considerably increased over that for several years past. During the early spring of 1901, the owners estimated, that fifteen car-loads of the rock per day were removed from the Pine Mountain quarries alone. The output varies of course from year to year, according to the demand.

The worked quarries are limited to the north and southwest slopes of the mountain, which slopes have been "raised" and worked from the base to near the top. The raise on the southwest side will average eleven feet in depth, and that on the north side will average about seven feet.

The chemical composition of this rock is given under the descriptions of the Crossley, the Arabia Mountain and the Southern Granite Company's quarries, pages 134, 138 and 140, which are extensions of the Pine Mountain rock.

The strength and durability of this stone are well brought out in the following physical tests:—[1]

Strength Tests Made on Two-inch Cubes

	Strength in lbs.	Strength in lbs. per Sq. Inch	Specific Gravity	Weight of One Cubic Foot
1	76,800	19,200	2.686	167.9
2	83,400	20,850	2.686	167.9
3	85,000	21,250	2.686	167.9
4	85,000	21,250	2.686	167.9

A test, made by Prof. F. W. Clarke, Chief Chemist of the U. S. Geological Survey, as to the capacity of the Lithonia granite-gneiss for absorbing water, gave, upon the immersion of one face in water for 48 hours, the following results:—[2]

Weight in grammes before soaking	381.5
Weight in grammes after soaking	381.7
Weight of water absorbed in 48 hours	.2 grm.

As Prof. Clarke remarks, the pair of weights are nearly identical, indicating that the stone would well withstand the disintegrating action of frost. The correctness of this test and the conclusions deduced therefrom are amply borne out in a close examination of the rock in its natural ledges in the field, and in those cases, where the writer has examined it in constructional work.

GWINNETT COUNTY

Extensive outcrops of contorted biotite granite-gneiss are found over various parts of Gwinnett county. A number of quarries have been opened, and large quantities of the stone, removed. The

[1] GRANITE PAVEMENTS.—A Comprehensive Review of the Pavements of the World. Also, a Treatise on Granite Paving, Comparative Tests Made, and other General Facts. Compiled by Messrs. Venable Bros., Atlanta, Ga., 1893, p. 21.

[2] Ibid., p. 15.

workable areas are grouped in an approximate north-and-south line about Lawrenceville, Trip, Snellville and Rosebud, as centres. The rock is apparently limited, therefore, to the central and middle-southern parts of the county, which represents the northern extension or prolongation of the DeKalb-Rockdale counties granite-gneiss area into Gwinnett county, for distribution of which, see map opposite page.

THE SAWYER QUARRY.—Several outcrops of the contorted biotite granite-gneiss occur in the south-central part of *lot 25, 5th district*, on a small stream three quarters of a mile northwest from Snellville. Some of the stone has been quarried and used in the buildings at Snellville. Hand specimens of the rock show a light-gray contorted biotite granite-gneiss, fine and close grained in texture.

Outcrops of the same rock occur on *lots 37, 38 and 39, 5th district*, one and a half miles northeast from Snellville. One surface raise has been made; but no stone has been quarried, save that a few surface rocks have been secured for chimneys etc., at various times.

Mr. J. Sawyer, of Snellville, is the owner of the property.

THE SNELL QUARRY.—A flat, dome-shaped mass of granite-gneiss with a steep western erosion slope, due to stream-cutting, outcrops two miles south from Snellville. The exposure includes at least 20 acres, in which four large openings have been made, and a large amount of stone, quarried. The first quarrying was done in 1883. The stone has been used mainly for blocks for street purposes, and as bridge abutments along the Seaboard Air Line railway; and, to some extent, as a building stone at Snellville. The rock is best suited for Belgian blocks, for street-paving. The rock appears in the hand specimen as a uniform and even banded, contorted biotite granite-gneiss, of medium grain. In some places, the rock-mass is cut by numerous pegmatitic veins, several inches in width.

Under the microscope, a thin section reveals a distinctly massive, granular rock, without trace of lamination or schistosity; and that it is composed of quartz and the feldspar species, microcline, orthoclase and plagioclase, with scattered folia of biotite occasionally intergrown with large irregular shreds of muscovite. The plagioclase and mica approach idiomorphic outlines as to crystal form, while the remaining constituents are wholly allotriomorphic. The grains of the various minerals are usually very irregular in outline, and form interlocking sutures of a highly complex character, with no resemblance whatever to a

A GENERAL VIEW OF THE SOUTHERN GRANITE COMPANY'S QUARRY, NEAR LITHONIA, GEORGIA, ILLUSTRATING THE WORKING OF A FLAT-SURFACE OUTCROP OF GRANITE-GNEISS.

rounded outline, suggestive of sedimentary origin. On the contrary, the entire mineral and chemical composition, as well as the physical characteristics of the rock, in thin section, are as typically igneous, as can well be found developed in any single igneous rock mass. The mineral grains are inequidimensional, forming a maize of both fine- and coarse-grained mozaics, of interknit quartz and feldspar. The potash feldspars, microcline and orthoclase, with the latter showing considerable microperthitic structure, are present in approximately equal proportions. Plagioclase, probably albite or very acid oligoclase, giving maximum extinction angles, $\infty P\infty$ (010) = 13° to 15°, is fairly abundant, and is readily distinguished from the other mineral species, by the broad polysynthetically twinned bars and the somewhat idiomorphic lath-shaped outline. The larger feldspar grains carry drop-like inclusions of quartz, and other feldspar species, revealing, in some cases, possible resorption rims or borders. Biotite is present as single filaments scattered sparingly through the section; but in a somewhat smaller proportion than that occurring in the granites elsewhere described in this report. It is deep brownish red in color, with strong absorption, and is largely altered to a dark, greenish-black, perfectly opaque chlorite, and occasional grains of highly double-refracting epidote. Several areas of large primary shreds of colorless cleavable muscovite, having somewhat noticeable absorption parallel to the cleavage, occur. Some secondary or derived muscovite and grouped garnets, of small size and of a slight cinnamon color, are present in microscopic proportions.

A chemical analysis of this rock, in the laboratory of the Survey, yielded the writer the following results: —

Silica, SiO_2	75.89
Alumina, Al_2O_3	14.02
Iron Sesqui-oxide, Fe_2O_3	0.71
Lime, CaO	0.70
Magnesia, MgO	0.12
Soda, Na_2O	3.64
Potash, K_2O	5.56
Ignition	0.28
Total	100.92

A comparison of this with the analysis of the similar rock, from the Tilly quarry in Rockdale county, shows but slight variation in the percentage amounts of the individual constituents of the two rocks.

Other physical tests made gave the following figures: —

Specific Gravity at 28°C.	2.642
Weight of one cubic foot of stone expressed in pounds	165.12
Number of cubic feet of stone contained in one ton (2,000 pounds)	12.1
Percentage (ratio) of absorption	0.075

Another outcrop of the same rock occurs on Dr. M. A. Born's Place, near the foot of the hill just above a small stream at the still-house, two miles east of Lawrenceville. Only a very small quantity of the rock has been taken out, for local use.

The Turner Quarry.—This quarry is approximately five miles southeast from Lawrenceville, and consists of six acres of exposed rock, in which three large openings have been made. A considerable amount of rock has been quarried from this locality, and used principally in railroad construction.

Macroscopically, the rock is a uniform, medium-grained biotite granite-gneiss, hard and firm in grain, lively in appearance, and practically free from the intersection of veins. The schistose layers or bands are less contorted in this locality, than in areas of the same rock, elsewhere observed. Usually, the mica appears to be somewhat lighter in color, imparting thereby a light-gray tint to the rock.

Microscopically, the rock (Museum No. 1,939) is allotriomorphic-granular. It is composed of an admixture of quartz, orthoclase, microcline and plagioclase, with a few small scattered biotite folia. Distinct zones and small areas of crushed mozaics of fine quartz and feldspar grains occur, partially surrounding the larger crystals of these minerals arranged along somewhat definite parallel lines, making the schistose structure quite apparent in the thin section. Long-drawn-out and slender foils of muscovite have been developed along the roughly parallel lines of fracture.

Hornblende Gneiss

Near the quarry described above, along the public road leading therefrom to Lawrenceville, and four miles southeast from that town, is an extensive body of a black, very thinly laminated hornblende-gneiss. Under the microscope, this rock (Museum No. 1,938) is composed of hornblende, epidote, orthoclase, plagioclase and quartz, named in the order of their relative abundance. The hornblende forms at least half of the mineral components of the rock. It occurs as allotriomorphic, massive grains, of a grass-green to a pale blue-green, in parallel polarized light, with strong absorption, and displaying partial cleavage-lines in some of the grains. The orthoclase and plagioclase are present in about equal proportions, and are wholly allotriomorphic in outline. Small rounded and highly double-refracting grains of epidote are abundantly distributed through the section, and are next to the hornblende in quantity. No biotite or augite is present in the thin section. What the rock originally was cannot be definitely stated;

but, at present, it forms apparently the equivalent of a dioritic hornblende-gneiss. No evidence appears to be present, either for or against the hornblende's being a primary or original constituent of the rock. The weathered product, resulting from the decomposition of this rock, forms a deep red and highly ferruginous, stiff clay.

THE EWING PROPERTY. — At Ewing's mill, one and a half miles southwest of Lawrenceville, directly under the mill-dam, the stream passes over an outcrop of rather coarse-grained biotite granite-gneiss. The schistose layers, or bands, of the rock have been only slightly contorted. No work had been done, up to the time of the writer's visit; but preparations were being made at that time, to quarry some of the stone.

This property is owned by Mr. M. E. Ewing, of Lawrenceville, Ga.

THE CATES QUARRY. — The opening on the Cates property, owned by Mr. G. W. Cates, Trip P. O., Ga., is very small. It is located half-a-mile northwest of the post-office, directly on the southwest side of the Lawrenceville public road. The outcrop contains something under an acre of exposed rock along the roadside in a cleared field. It is a coarse-grained biotite granite-gneiss, in which no contortion of the laminæ was evident. The small amount of rock quarried was used for railroad purposes.

THE TRIBBLE AND BENNETT PROPERTY. — Approximately two acres of flat-surface outcrop are exposed, three quarters of a mile north of Trip P. O. It lies partly on Mr. W. J. Tribble's and partly on Mr. A. Bennett's property, with the small opening, from which some rock has been quarried, on the former's place. It is an excellent grade of very uniform and even, fine-grained, banded biotite granite-gneiss, with the layers slightly contorted.

THE LANGLEY QUARRY. — Approximately two to three acres of flat-surface outcrops occur two miles south of Trip P. O. on the property of Mr. Thomas Langley, and directly in front of his dwelling-house. The rock is a medium coarse-grained, slightly contorted biotite granite-gneiss, lively in appearance, easily worked, and comparatively free from intersecting veins.

Under the microscope, a thin section of this rock (Museum No. 1,932) reveals an allotriomorphic-granular texture, without a trace of schistose structure, so characteristic of the rock in the hand specimen. It is composed of quartz, orthoclase, microcline and plagioclase, with small biotite filaments, almost entirely altered to the dark colored and opaque chlorite and occasionally, epidote. It is quite similar microscopically to the rock occurring at Lawrenceville and Rosebud (Museum Nos. 1,907 and 1,928), with the single exception of its containing, probably, somewhat increased amounts of microcline and plagioclase. The partially idiomorphic plagioclase gives small average extinction angles in basal sections. The feldspars and quartz combined, make up fully 95 per cent. of the total mineral composition of the rock-mass. Both primary and secondary shreds of muscovite are present in microscopic proportions. The larger feldspar and quartz grains are badly fractured in many cases, and are partially surrounded by fine-grained, crushed mozaics of these minerals.

THE MAYFIELD PROPERTY.—An extensive exposure of flat-surface outcrops of granite-gneiss, containing a dozen or more acres, occurs a quarter of a mile north from Rosebud P. O., on Bushy creek just off the public wagon-road, on the property of Mr. E. W. Mayfield. Two small openings have been made; but practically no rock has been quarried. The rock is a coarse-grained, slightly contorted biotite granite-gneiss, of good quality.

Microscopically, the rock (Museum No. 1,928) is composed of quartz, orthoclase, microcline and plagioclase, with small biotite plates, greatly altered. The schistose structure is not evident under the microscope. In texture, the rock appears to be allotriomorphic-granular. It differs from the Lawrenceville rock (Museum No. 1,907) in containing an increased amount of plagioclase, and in the microperthitic structure's being less abundant. The derived or secondary minerals present are chlorite, muscovite and epidote. A few garnet crystals, of irregular outline, occur, and are partially double-refracting under crossed nicols. They are crossed by lines of fracture, which, in connection with the other evidence present, illustrates mechanical strain in the rock-mass.

THE LAWRENCEVILLE QUARRY.—Approximately 460 yards from the main line of the S. A. L. railway, just outside of the corporate limits of the town of Lawrenceville, are from three to four acres of flat-surface outcrops of biotite granite-gneiss. This property is owned and controlled at present by Mr. W. L. Vaughan, of Lawrenceville. The quarry has been worked to a depth of about ten feet, and a large amount of the stone has been taken out. This was used principally along the line of the S. A. L. railway. The rock is the same contorted, light-gray, biotite granite-gneiss described from other localities in Gwinnett county.

Microscopically, the rock (Museum No. 1,907) consists of fine- and coarse-gained mozaics of quartz and feldspar, occupying well defined and definitely related areas. The mineral composition of the rock is made up of quartz and the feldspar species, orthoclase with microperthitic structure, microcline and plagioclase, with numerous biotite plates. The feldspar constituent, as stated above, is composed of the potash species, orthoclase and microcline, with the former predominating, and numerous laths of plagioclase. The larger feldspar and quartz grains enclose smaller microscopic grains of the two minerals, of irregular outline. Biotite is very sparingly present in the thin section, and is almost entirely altered to a dark, opaque chlorite. Some secondary shreds of muscovite, irregularly shaped grains of epidote, and occasional microscopic inclusions of zircon are present.

A similar rock, of equally good quality, occurs on the Bennett and Whitworth Property in the lower part of this county.

THE McELVANEY SHOALS PROPERTY. — This property is located three miles northeast from Loganville, Walton county, eight miles east from Lawrenceville, and approximately three and a half miles southeast from Trip P. O. in Gwinnett county, with the main body of the rock lying about one and a quarter miles east of the Lawrenceville-Loganville branch of the S. A. L. railway. The present owners of the property are Messrs. Nathan Bennett, H. M. Whitworth, A. L. Bell, Robert Livsey and J. T. McElvaney and Dr. R. A. Hammond. The main body of the rock consists of some 200 acres, or more, of continuous outcrops along the upper course of Bay creek, which is a fair sized stream flowing immediately over the exposed rock. At this point, the stream has a southeast course, and the rock outcrops for a distance of approximately one mile along the stream, and extends back on either side for from a quarter- to a half-mile. The surface of the rock has an angle of slope toward the stream on the two sides, of 10° to 20°. The stream has a fall of 200 feet in the one mile of rock exposure, over which it courses. The fall is not equally distributed ; but, starting from the present mill location and following the stream northwest to the dam, a 100-foot fall occurs in a distance of 1,076 feet. From the above description, it naturally follows, that a sufficient power can be obtained for operating almost any kind of a plant, of average size.

The rock is a medium-grained, light blue-gray biotite granite-gneiss, which, in places, apparently grades into a lighter-colored, banded rock, of the same texture, but carrying a much smaller amount of biotite. Gradations into small areas of a massive, fine-grained granitic rock, and without a trace of schistosity were observed. Generally the rock is uniformly banded, displaying but slight contortion of the layers. The rock-mass is cut, in places, by pegmatitic dikes and veins, of a few inches in width; but these are not sufficiently abundant to in anywise injure the rock.

Under the microscope, a thin section of the rock (Museum No. 2,014) reveals the presence of the feldspars, microcline, orthoclase and plagioclase, quartz and biotite. The usual cataclastic phenomena, described above for other areas of similar rock occurring in this county, are observed in the thin section. A chemical analysis of the rock, in the Survey laboratory, yielded the writer the following results:—

Silica, SiO_2	68.89
Alumina, Al_2O_3	16.47
Iron Sesqui-oxide, Fe_2O_3	2.34
Lime, CaO	1.63
Magnesia, MgO	0.40
Soda, Na_2O	4.38
Potash, K_2O	4.15
Ignition	0.32
Total	98.58

From the above analysis, it will be observed, that the potash and soda feldspars are present in nearly equal proportions. The percentage of iron oxide is approximately normal for this type of rock, its source being, in this case, from the black mica, biotite, and not from any free oxides or sulphides present in the rock.

From an examination of the parent ledges, the rock apparently withstands the attack of atmospheric agencies to a remarkable degree. The effects of weathering are indicated to only a slight depth from the surface. The rock becomes disintegrated, and finally crumbles into a coarse-grained granitic sand, through temperature changes, hydration and kaolinization of the feldspars—granulation. The mica flecks are distributed through the sand in a fairly fresh condition, the final product manifesting but little effect from chemical decomposition.

THE BUSH QUARRY.—A quarter of a mile south from Winder, some dozen or more acres of contorted biotite granite-gneiss are exposed on the property of Mr. W. H. Bush, of Winder, Georgia. A number of openings have been made in different places, and a considerable amount of the stone has been quarried. The Gwinnett-Walton county-line divides the property, placing the openings partly in Gwinnett county and partly in Walton. Hand specimens of this rock cannot be distinguished from those from the Saunders quarry in Jackson county. So far as the quarrying extends, the rock in the Bush quarry appears not so highly contorted as that of the Saunders quarry. Further, it shows considerable variation in color and texture, and is cut by numerous pegmatite veins. When the rock is broken at right angles to the schistosity plane, the fractured surface presents roughly an "augen-gneiss" appearance—the quartz and feldspar grains being partially lens-shaped and irregulary wrapped by the layers of biotite.

A number of buildings in Winder have been entirely constructed of this rock. It has also been used as foundations in other buildings, and for street work. Several large shipments of the rock have been made to Gainesville, Georgia, where it has been used for street pavements.

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-surface masses. So far as the writer has been able to trace it, the Jackson County outcrops mark the northernmost extension of the DeKalb-Rockdale-Gwinnett counties' 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 quite uniform and highly contorted, and is composed of an admixture of quartz, feldspar and biotite. It can hardly be distinguished, in the hand specimens, from the similar rock quarried at Lithonia; although slight differences are discernible between the rocks of the two localities, on close inspection. 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, not altogether so highly crumpled, as the typical granite-gneiss at Lithonia. The variations are regarded as very slight indeed, for the extreme portions of so extensive a granitic area.

THE SAUNDERS QUARRY.—Three-quarters of a mile north of Winder, four openings have been made close to each other, in flat-surface outcrops of the contorted biotite granite-gneiss. The openings are small, and the stone quarried has been used, with one exception, in the immediate locality, for curbing and building. One shipment of the rock was made to South Carolina. The quarry is owned by Dr. J. M. Saunders, of Winder, Ga.

THE STANTON AND DELLEPIERRE OPENING.—A quarter of a mile west of the Saunders quarry, a small opening in the same rock has recently been made on the property of Mr. Z. F. Stanton and Dr. J. C. Dellepierre, of Winder, Ga. No stone has been shipped. The rock quarried is worked into curbing. The writer was informed, however, that work would be resumed shortly on a more extensive plan.

WALTON COUNTY

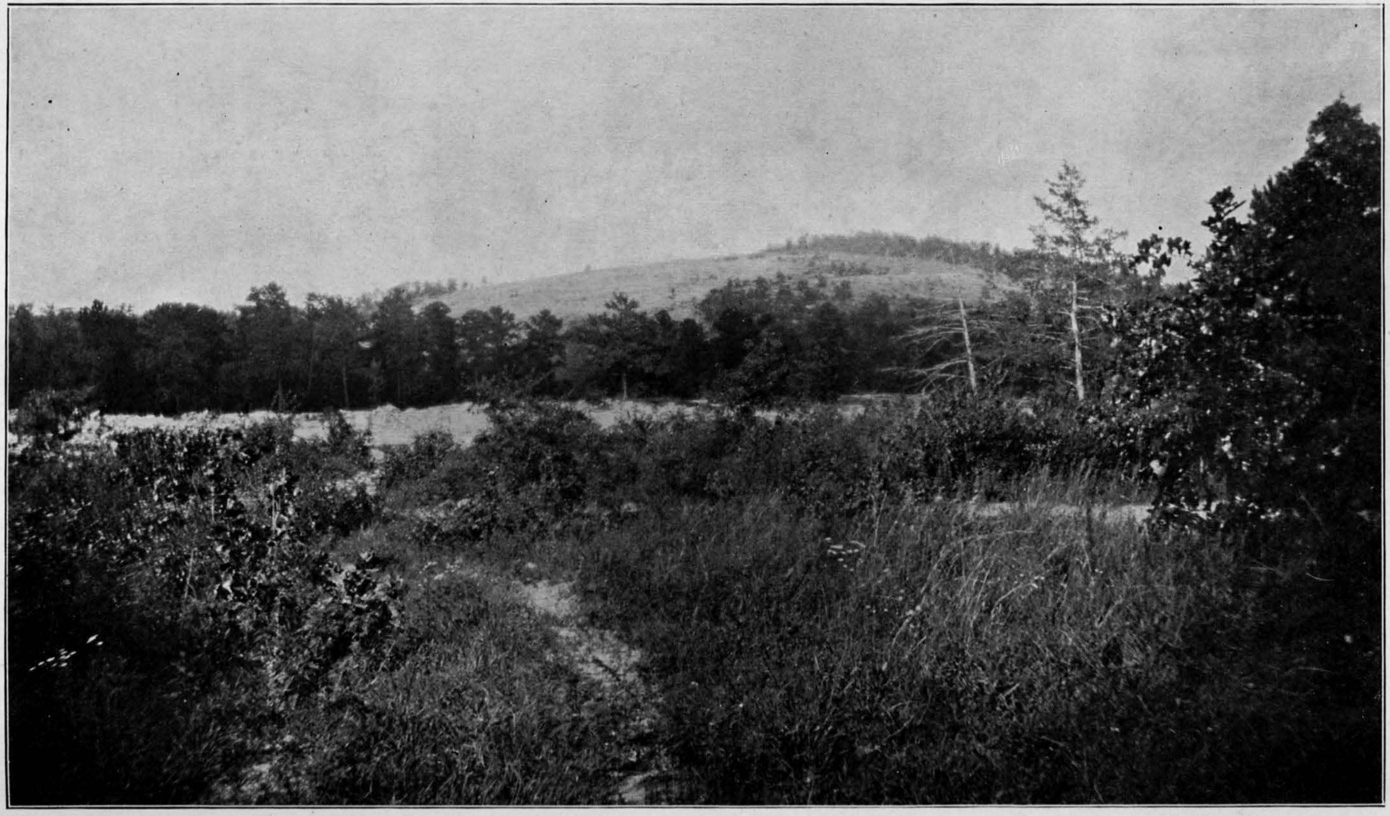
The DeKalb-Rockdale-Gwinnett counties area of contorted biotite granite-gneiss occupies an extensive portion of the eastern part of Walton county. With the exception of one or two small patches of schist and hornblendic rock, the Winder-Loganville public road traverses the granite-gneiss area for the entire distance of 18 miles. But few fresh exposures of the rock are seen along the road; although it is readily identified by its residual decay, which extends to some depth, and preserves, in a perfect manner, the structure of the fresh rock.

Two dikes of diabase were found cutting the granitic mass some distance to the southwest of Winder along the public road. The first one, one and a half miles southwest of Winder, is several hundred feet wide. The second one, eleven miles southwest of the same town, and along the same road one mile northeast of Alcovy river, is not more than a few yards in width.

Gullies, 15 to 20 feet deep, 30 to 60 feet wide, and proportionately long, trenched in the decayed rock, are conspicuous in many places along the road between the towns of Winder and Loganville. These sections show, for the first foot or two from the surface, a highly ferruginous, gritty clay, grading into the grayish-white decayed rock beneath, which readily falls to pieces in the hand, but which shows the entire details of the original structure. In the lower part of the sections, at an average of several feet from the surface, the biotite of the decayed rock has suffered no appreciable change from alteration; but the feldspars are apparently in an advanced stage of kaolinization.

Less than half-a-dozen openings have been made in Walton county, from which rock has been quarried.

The Windsor Bridge Opening. — On the southwest side of Alcovy river, at Windsor bridge, along the Winder-Loganville public road, a small opening has recently been made, from which stone was obtained for building the bridge over the river. Extensive exposures of the rock are observed, for some distance along the river, at this point, reaching back several hundred yards on either side of the stream.



A VIEW OF PINE MOUNTAIN, LITHONIA, GEORGIA, AN UNREDUCED RESIDUAL OF GRANITE-GNEISS, FROM A POINT OF VIEW, A QUARTER OF A MILE AWAY.

THE LOGANVILLE GRANITE-GNEISS AREA

For several miles on the north, northeast and south sides of Loganville, more or less continuous outcrops of the contorted granite-gneiss are exposed. Several openings have been made, within a mile of the town of Loganville, and some of the rock has been quarried for home consumption. Some local variations in color and texture in the rock, exposed in this locality, are shown.

THE ROCKMORE QUARRY.—Three-quarters of a mile south of Loganville on the property of Mr. J. P. Rockmore, of Loganville, at least six acres of flat-surface outcrops of the granite-gneiss occur. Three small openings have been made near each other, in different places, and enough of the stone has been quarried, to construct several buildings in the town. Only one car-load of the stone has been shipped out of the county. The flat exposures of the rock grade into a 20° to 30° slope to the south, offering easy conditions for quarrying.

Hand specimens of this rock cannot be distinguished from those of the typical Lithonia "granite". It possesses all the good qualities of the latter rock, and is equally as well suited for the same uses.

The quarry faces show the usual sprinkling of magnetite grains, commonly observed in the quarries at Lithonia.

THE BRASWELL OPENING.—Near the northern limits of the town of Loganville on the Lawrenceville public road, a small opening has been made, and a few feet of the stone, quarried. The opening is on the property of Mr. W. H. Braswell, of Loganville.

THE STEPHEN BRAND OPENING.—On the property of Mr. Stephen Brand, of Loganville, a half to three quarters of a mile northeast of the town, on Flat creek, some of the granite-gneiss has been quarried, from time to time, for chimneys in the county.

ROCKDALE COUNTY

Rockdale is the adjoining county on the southeast to DeKalb, and lies immediately south of Gwinnett and Walton counties. The granitic rock found in this county is a continuation of the Lithonia "granite" belt in DeKalb county. It is continuous over large areas of Gwinnett, and is a highly contorted biotite granite-gneiss. The rock outcrops as boulders, ledges, flat surfaces and dome-shaped masses, over the greater part of the central and northern half of the county. Numerous quarries have been opened and operated, from time to time, in the section around about Conyers, the county-seat. The rock is a very superior one for Belgian blocks and curbing, being easily quarried, of excellent quality, and possessing great durability and permanence. The bulk of the stone quarried in this county has been used in street work, principally as Belgian blocks. No massive granites are known in Rockdale county.

THE MCDANIEL MOUNTAIN PROPERTY. — This is a dome-shaped mass, containing a fraction over 31 acres, and rising to an approximate elevation of 100 feet above the surrounding lowland plane, with a gentle slope on all sides from the center, and with its longer axis trending in a northeast-southwest direction. It is located on *lot 174, 16th district*, some 300 to 400 yards southeast of the DeKalb county-line, and three quarters of a mile east of the north peak of Arabia mountain, in DeKalb county.

The present owner of the property, Mr. John W. McDaniel, sold the entire tract in 1894 to the Lithonia Co-operative Granite Company, of Lithonia, Ga., when considerable stone was quarried and worked into blocks. The worked quarries, of which there are a number, are confined to the west and southwest slopes of the peak. On the south and northwest slopes, are three raised-sheet quarries ready to be worked.

The rock is a light-gray, irregularly banded, and highly contorted biotite granite-gneiss. In texture, it is medium-grained, and the component minerals, quartz, feldspar and biotite, are readily identified in the hand specimen. The rock is cut, in places, by a few veins of mixed feldspar and quartz; and, at times, it carries a somewhat large sprinkling of magnetite grains. Large quantities of first-grade stone can be easily and readily quarried on this property.

The rock weathers through the hydration and oxidation of the biotite and feldspars, which, in the most advanced stage represented, yields a yellowish colored, kaolinized granite sand, through which are distributed the partially decomposed and leached mica (biotite) folia.

A short distance to the southeast of the granite-gneiss, is an extensive body of mica-schist, readily traceable along the wagon-road to and beyond the McDaniel mill, three-quarters of a mile southeast from the gneiss outcrop. The exact contact between the gneiss and schist could not be made out, owing to the heavy mantle of residual decay; but no apparent gradation from one to the other was anywhere apparent.

THE TURNER QUARRY. — This quarry is located in the southern part of *lot 201, 16th district*, and consists of from six to eight acres of exposed rock, occupying the west slope of a gently sloping hillside, about one mile from the Georgia railroad. The quarry was first opened in 1890, and a large quantity of the rock has been taken out, to be used mostly for Belgian blocks.

The rock is a light-gray contorted biotite granite-gneiss, carrying considerable magnetite grains, in places. Occasionally garnetiferous layers are met with, and the rock is cut, at times, by veins of quartz and feldspar.

Under the microscope, a thin section reveals an allotriomorphic-granular rock, composed of an aggregate of complexly interlocking grains of quartz and the feldspar species, orthoclase, microcline and plagioclase, with biotite shreds variously altered to chlorite and some epidote. The potash feldspars, orthoclase and microcline, make up the predominant mineral species present. Microperthitic intergrowths, twinning and zonal structures, are well developed in the feldspars. Small areas of crushed mozaics of quartz and feldspar are apparent along the peripheries of some of the larger quartz and feldspar grains, and numerous fracture planes and irregular double-refraction, common to the quartz and feldspar anhedra, furnish other evidences of dynamo-metamorphism. The schistose structure, while characteristically marked in the hand specimens, is not at all evident under the microscope.

THE REAGAN PROPERTY. — Outcrops of the same rock, as that described under the Turner quarry, occur approximately 100 yards to the east of that quarry, on adjoining properties owned by Messrs. E. O. Reagan and Kerr Reagan respectively. The Reagan exposures are about 150 yards apart, and some rock has been quarried from each outcrop. The E. O. Reagan outcrop is the more extensive one, including some half-dozen acres of exposed rock. The rock quarried was worked into Belgian blocks for street use. It is a light-gray, contorted biotite granite-gneiss, composed of quartz, feldspar and biotite, carrying a few grains of magnetite, and cut in places by small veins.

The weathering of this rock was very forcibly illustrated in a large boulder, exposed on the top of the quarry ledge. The boulder had partially crumbled to a medium coarse-grained quartz-feldspathic sand, containing practically no ferruginous stain or color, and through which was found distributed shreds of biotite, in an almost fresh condition. The feldspars were evidently the minerals affected by the atmospheric agencies, and the rock crumbled through the effect of hydration and subsequent kaolinization of the feldspar.

THE BROOKS PROPERTY. — On the north side of George's creek, near the top of the southeast slope of the hill, and in front of the dwelling-house of the owner, Mr. Josiah Brooks, are several acres of the granite-gneiss exposed as a ledge outcrop. It is an excellent grade of granite-gneiss, very uniform in grain and color, and lively in appearance. Only a very small amount of the rock has been quarried. It is the same light-gray, contorted biotite granite-gneiss described above, and is only a short distance from the Reagan outcrop. It is composed of interlocking quartz and feldspar grains, with shreds of biotite.

THE TILLY QUARRY. — This property, two miles northwest of Conyers, includes 242 1-2 acres in the entire tract, and has only recently come into the possession of Mr. J. R. Tilly, of Conyers. It was formerly owned by a Mr. Sigman and a Mr. Clark, at different times, and was known then as the Sigman property and the Clark property, respectively. Approximately from four to six acres of the rock outcrops as flat surfaces; and three openings have been made in close proximity to each other, and a large quantity of the stone has been quarried.

Hand specimens indicate the same highly contorted, light-gray biotite granite-gneiss, carrying the usual sprinkling of magnetite, from which staining results on prolonged exposure, as described above.

Under the microscope, a thin section reveals a medium-grained, allotriomorphic-granular rock, composed of quartz and the feldspars, orthoclase, microcline and some plagioclase, with scattered foils of biotite as the chief accessory mineral. The potash feldspars, orthoclase and microcline, are in excess of the other mineral species present, with quartz next in abundance. The quartz anhedra are variously fractured, and display irregular double-refraction between crossed nicols. The various feldspar species present their usual distinctive characteristics; and, taken with the quartz, they make up probably more than 95 per cent. of the rock. The orthoclase shows considerable microperthitic structure, and is present in approximately equal proportion with the microcline. The plagioclase is only sparingly present, as stout laths, displaying the broad, polysynthetically twinned lamellæ. Drop-like inclusions of quartz and feldspar are common to the larger feldspar grains. Biotite, with its usual brown color and strong absorption, occurs as slender foils, somewhat altered to chlorite and epidote. Some zircon inclusions, and a few shreds of secondary muscovite were observed.

A chemical analysis of a specimen of the rock from this locality yielded the writer the following results: —

Silica, SiO_2	75.45
Alumina, Al_2O_3	13.71
Iron Sesqui-oxide, Fe_2O_3	0.92
Lime, CaO	0.94
Magnesia, MgO	0.18
Soda, Na_2O	3.87
Potash, K_2O	4.30
Ignition	0.40
Total	99.77

A comparison of this analysis with analyses of the similar rock from DeKalb and Gwinnett counties reveals their practical identity.

Physical tests made by the writer resulted as follows: —

Specific Gravity	2.643
Weight of one cubic foot of stone expressed in pounds	165.18
Number of cubic feet of stone in one ton (2,000 pounds)	12.10

THE POWELL QUARRY.—This quarry is located about two miles east of Conyers, and is owned by Mr. C. Anderson of that place. About four acres of the rock are exposed on a gently rolling hillside, with approximately a 10°-angle of slope. The quarry was last worked in 1896.

Four openings have been made in different places over the outcrop, and a large quantity of the stone has been quarried and worked into blocks. The rock is a highly contorted, light-gray biotite granite-gneiss, containing numerous garnets, in places.

Under the microscope, a thin section indicated an allotriomorphic-granular rock in texture, composed of intricately interlocking anhedra of quartz, and the feldspar species, orthoclase, microcline and plagioclase, with a small proportion of biotite as the chief accessory mineral present. The grains of the component minerals, are very irregular in size and outline. Roughly rounded, enclosed grains of quartz and feldspar are common to the larger grains of these two minerals. The essential minerals present their characteristic optical properties, by which they are easily identified. Occasional primary foils of muscovite occur interfoliated and intergrown with the biotite. Muscovite is present in rather increased amounts, as a derived or secondary product. Epidote and chlorite, also occur as secondary products, derived from the biotite. Micropegmatitic intergrowths of quartz and feldspar are observed under the microscope. Dynamo-metamorphism manifests itself in crushed and interlocking fine-grained mozaics of quartz and feldspar, occurring along the sutures of the larger quartz and feldspar individuals; also, numerous planes of fracture and irregular double-refraction, common to the larger grains of quartz and feldspar.

THE ALMAND QUARRY.—This quarry, which is owned by Mr. D. M. Almand, of Conyers, is located on the Tan-yard branch, just outside of the western limits of the town of Conyers, occupying the west slope of the stream. The stream is small; is characterized by a broad valley; and has corresponding gently sloping sides. Several acres of exposed rock are shown in the outcrop. The rock is the same highly contorted light-gray biotite granite-gneiss as that described above; but, where exposed, it is cut by numerous pegmatitic veins. With the exception of the vein occurrence, the rock is an excellent grade of stone. A small amount of it has been quarried.

THE WHITTAKER QUARRY.—Three quarters of a mile slightly west of south from Conyers, there are approximately five acres of horizontal-surface outcrops of the contorted granite-gneiss. The rock was being worked, at the time of the writer's visit, under lease on a royalty. Three openings had been made, and the writer was informed, that the stone was quarried for street purposes, to be used outside of the State. The rock is the same highly contorted, light-gray biotite granite-gneiss described above.

THE REDWINE AND JAMES QUARRIES.— Two quarries of granite-gneiss near Conyers are owned by Messrs. J. B. Redwine and John H. James, of Atlanta. One of these is located on the south edge of Conyers, in a two-and-a-half-acre flat-surface outcrop of the rock. It was first opened and worked about 12 years ago by Mr. Geo. W. Collins. No work has been done since. The rock is a light-gray, contorted biotite granite-gneiss, of good quality.

The other quarry[1] is located just outside of the west limits of Conyers, on the northeast side of the Tan-yard branch, not far from the Almand quarry. The outcrop at this point includes approximately five acres of horizontal sheets, with two openings, from which rock has been quarried. The rock at this locality presents a somewhat more massive appearance than the typical Lithonia gneiss, although it is the same rock. The quarry has been operated at two different periods. It was first opened 12 years ago, and was again worked about two years after that. The stone is of excellent quality, and a large amount has been quarried. It is a light-gray contorted biotite granite-gneiss, containing some small segregations of biotite, in places.

Microscopically, the rock is composed of quartz, the potash feldspars, orthoclase and microcline, and plagioclase feldspar, with biotite. The quartz and feldspar grains are very irregular, as regards size and shape, and the larger ones carry drop-like inclu-

[1] Also known as the Houston quarry.

sions of quartz and of other feldspar species. Plagioclase is rather abundant as stout laths, displaying the broad, polysynthetically twinned bars. Microperthitic, zonal and twinned structures occur well developed, and are quite common to the feldspar species. Biotite has its usual characteristic occurrence, color and absorption, and is variously altered to chlorite and some epidote. Muscovite, as a derived or secondary product, is rather abundantly distributed through the section.

THE PIERCE QUARRY. — Approximately three or more acres of flat-surface outcrops of granite-gneiss, occur three miles a little west of north from Conyers, immediately overlooking Yellow river, on the gently sloping southwest bank of the stream. The property is owned at present by Mr. Lucius Brooks, of Conyers. The quarrying has been on rather an extensive scale, resulting in a large quantity of the stone being worked into blocks for street purposes. The last work was done some six or seven years ago.

An examination of this outcrop reveals the same highly contorted schistose, light-gray biotite granite-gneiss, as that described above, from other localities in Rockdale county. Numerous grains of magnetite (an iron oxide) are distributed through the rock, which proves a source of discoloration, on exposure to the atmospheric agencies.

Microscopically, this is a medium fine-grained, allotriomorphic-granular rock, without a trace of the marked laminated or schistose structure, shown in the hand specimen. The rock is composed of an aggregate of inequidimensional, complexly interlocking grains of quartz, plagioclase, and the potash feldspars, orthoclase and microcline, with biotite shreds more or less altered to chlorite and some epidote. Microperthitic, zonal and twinned structures are quite characteristic of some of the feldspar grains. Dynamometamorphism is manifested in the numerous lines of fracture crossing the essential minerals; the strong wavy extinction characterizing the quartz; and the small areas of crushed mozaics of fine-grained quartz and feldspar present in the thin section, under the microscope.

THE PAPER-MILL QUARRY. — An extensive outcrop of granite-gneiss occurs on the south-side of Yellow river, two miles north from Conyers and a quarter of a mile from the paper-mill. The rock exposure is continuous on the two sides of the stream and in its bed. The enclosing walls of the stream, where the rock outcrops, have an angle of slope varying from 30° to 45°. Only a very small amount of stone has been quarried. The rock is a contorted biotite granite-gneiss, as described from various other localities in this county. It contains, in the hand specimen, considerably more biotite, which renders the stone somewhat darker in color, than the same rock noted from the numerous places described above. While the rock is a distinctly banded granite-gneiss, the contorted condition of the layers is less plainly marked than in other localities. Muscovite occurs rather abundantly, in places, and the rock is cut by numerous veins varying from a fraction to several inches in width. In texture, it is somewhat coarser-grained, carrying, in places, more garnets than elsewhere observed.

Under the microscope, a thin section shows an aggregate of quartz and the feldspar species, orthoclase, microcline and plagioclase, with biotite. The texture is allotriomorphic-granular, as contrasted with idiomorphic-granular. The feldspar is greatly altered in some cases to muscovite. Enclosed grains of quartz and feldspar in the larger crystals of these minerals abound. Micropegmatic intergrowths of quartz and feldspar, and microperthitic, twinning and zonal structures are common among the feldspars. Chlorite, epidote and muscovite occur as secondary products. A few shreds of original or primary muscovite are intergrown with the biotite. Mechanical stress is evident in the great number of fracture lines crossing the quartz and feldspar grains, which, in many cases, have been subsequently filled with mineral matter; in the marked irregular double-refraction of the quartz anhedra, under crossed nicols; and in the numerous small areas of fine-grained mozaic of quartz and feldspar, occurring along the sutures of the larger individuals of these two minerals.

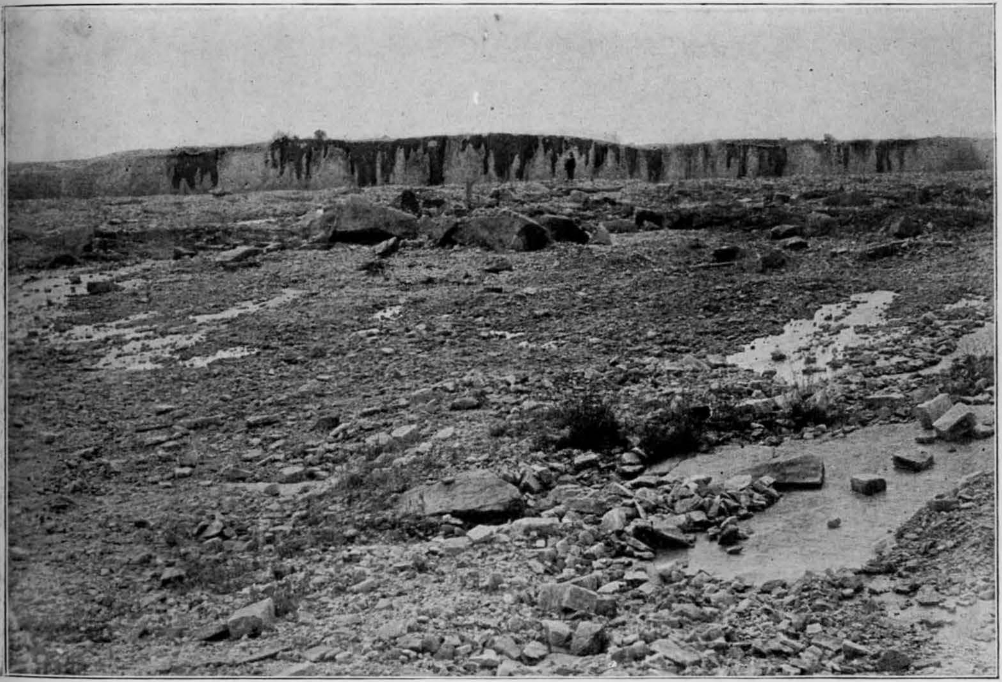
This property is owned by Messrs. Almand & Wellhouse, of Conyers.

THE GOODE QUARRY. — Located about a quarter of a mile west from the Almand quarry, on the same hillslope, but well up on top of the hill, almost opposite the Redwine and James quarry, are three or four acres of the flat-surface outcrops of contorted granite-gneiss. The rock is the same highly contorted biotite granite-gneiss described above, and contains abundant grains of magnetite, of rather large size. Only a small quantity of stone has been quarried.

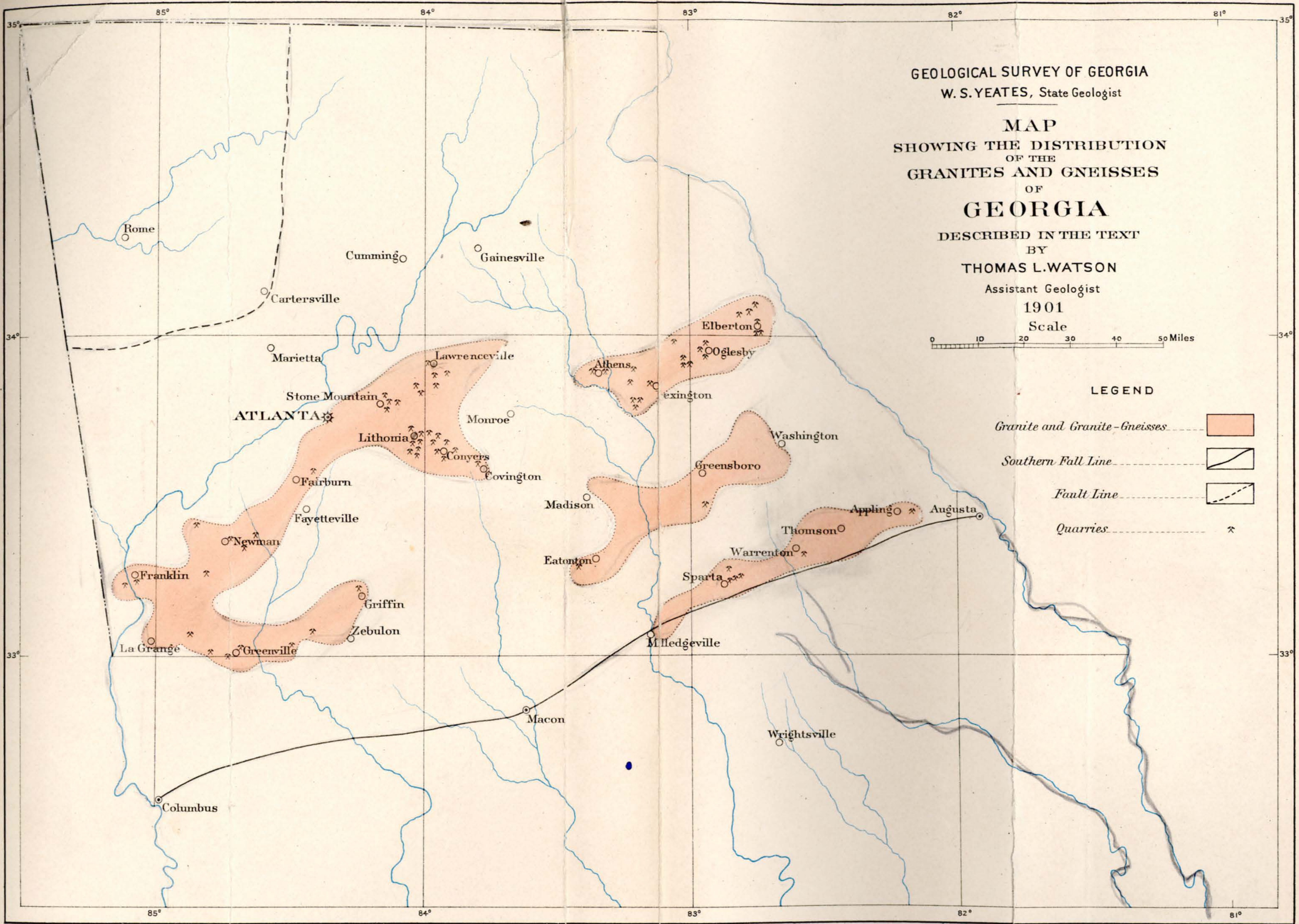
OTHER OUTCROPS OCCURRING IN ROCKDALE COUNTY, WHERE QUARRIES HAVE NOT BEEN OPENED

About from three and three-quarters to four miles a little west of north from Conyers, on the Conyers-Lawrenceville wagon-road, is an extensive outcrop of the contorted biotite granite-gneiss, in-

Fig. 2



GRANITE-GNEISS QUARRIES, PINE MOUNTAIN, LITHONIA, GEORGIA. FIG. 2 SHOWS THE QUARRY-FACE AND THE QUARRY BOTTOM AT THE SURFACE OF THE DOMING MASS.


GEOLOGICAL SURVEY OF GEORGIA
W. S. YEATES, State Geologist
MAP
SHOWING THE DISTRIBUTION
OF THE
GRANITES AND GNEISSES
OF
GEORGIA
DESCRIBED IN THE TEXT
BY
THOMAS L. WATSON
Assistant Geologist
1901
Scale
0 10 20 30 40 50 Miles
LEGEND
Granite and Granite-Gneisses
Southern Fall Line
Fault Line
Quarries
85° 84° 83° 82° 81°
35° 34° 33°
Rome
Cumming
Gainesville
Cartersville
Marietta
Lawrenceville
Stone Mountain
ATLANTA
Lithonia
Conyers
Covington
Monroe
Athens
Elberton
Oglesby
Lexington
Washington
Greensboro
Madison
Eatonton
Fairburn
Fayetteville
Newman
Franklin
Griffin
Zebulon
La Grange
Greenville
Appling
Augusta
Thomson
Warrenton
Sparta
Milledgeville
Macon
Wrightsville
Columbus
A. HOEN & CO. BALTIMORE

cluding more than half-a-dozen acres in the exposure. A second outcrop of the same rock occurs along the same road on Mr. J. F. Camp's place, five and a half miles north of Conyers. Again, six and a half miles north of Conyers, is an extensive outcrop of this rock, on Mr. J. F. Peek's place. A few chimney and cemetery stones have been gotten, from time to time, at the two latter outcrops.

A summary of the characteristics, qualities etc. of the rock from this county will be included in a general résumé of the granites and gneisses in DeKalb, Gwinnett and Rockdale counties.

NEWTON COUNTY

Newton joins Rockdale county on the east. It contains a number of areas of coarse-grained, irregularly-banded biotite granite-gneisses, well suited for street purposes and rough masonry. Several openings have been made in rock exposures at numerous points, and some rock, obtained for local use; but only one quarry has been worked to any extent. Residual decay, resulting from the decomposition of the rock, extends to an unusual depth over most of the county, and covers the bed-rock to such an extent, that the rock-outcrops are greatly reduced in number, and are small in area. The only area studied is in the northern part of the county in the neighborhood of Covington, the county-seat. Two rather large outcrops, in the shape of flat surfaces, occur — one, two miles northwest of, and the other, one and a half miles southeast from, the town of Covington. No typical massive granites have been found in Newton county.

THE PERRY PROPERTY. — This body of rock has never been worked; but, at the time of the writer's visit, the surface was being raised for the purpose of getting stone for the Porterdale factory in Newton county. There are several acres of flat-surface outcrops in the rock-mass, located one and a half miles southeast from Covington. The rock is a coarse-grained biotite granite-gneiss, of very dark color, due to the large amount of biotite (black mica) present. In some parts of the mass, the rock becomes a true "augen-gneiss", in which the feldspars are well drawn out lens-shaped areas or masses, surrounded by the black biotite. In other portions, the action of the metamorphic agencies has resulted in a re-arrangement and differentiation of the light-colored minerals, feldspar and quartz, from the biotite, forming distinct and somewhat evenly defined bands.

This property is owned by a Mr. Perry, of Covington, Ga.

THE FREEMAN QUARRY. — This quarry is located two miles northwest from Covington, near the Georgia railroad, on the property of Mrs. M. L. Freeman, of that town. The outcrop includes two or more acres of exposed flat rock. Considerable work has been done, and a large amount of stone, quarried and used chiefly for street-paving purposes, although some of it was used in the construction of local buildings, nearby. The quarry had been worked to a depth of from 25 to 35 feet in several places.

Megascopically, the rock is a coarse-grained, somewhat contorted and extremely irregularly banded biotite granite-gneiss, of a dark-gray color. Metamorphism has produced a nearly complete differentiation and re-arrangement, along roughly parallel lines, of the light colored minerals, quartz and feldspar, from the ferromagnesian mineral, black biotite. The bands vary greatly in thickness and outline. When compared with the contorted granite-gneiss from the Lithonia belt, the variation in texture, grain and color is very striking. Apart from being coarser-grained and darker in color, it lacks the hardness, compactness, and lively appearance of grain, so characteristic of the Lithonia granite-gneiss. This difference can possibly be accounted for, in great measure, in the difference in degree of intensity of the metamorphism; as a comparison of the two areas indicates a more profound dynamic action in the Lithonia, than in the Covington area.

Under the microscope, a thin section of the rock indicates a coarse-grained biotite granite-gneiss, without trace of schistose structure, and composed of anhedra of quartz and feldspar, with scattered folia of biotite, almost wholly altered to chlorite. The feldspars, including all species present, form the most abundant constituent. Named in the order of abundance, they consist of microcline, orthoclase and plagioclase. Microcline occurs in large allotriomorphic grains, complexly twinned according to the albite and pericline laws, and enclosing rounded and irregular grains of other feldspar species and quartz. Plagioclase is fairly abundant. It is present usually in somewhat large and roughly lath-shaped crystals, showing polysynthetic twinning, and is badly altered to minute scales of muscovite and kaolin. The orthoclase usually shows good cleavage and, in some instances, microperthitic structure; but the latter is very much less common than hitherto observed. Micropegmatitic intergrowths of quartz and feldspar are somewhat common. Biotite is the chief accessory mineral. It is much more abundant in the hand specimen, than in the thin section under the microscope.

The mineral grains interlock in a most intricate fashion, and do not display any evidence of roundness in outline. The quartz and some of the feldspar grains exhibit numerous marked fracture-planes, crossing the crystals in all directions, indicating mechanical stress.

A chemical analysis of this rock, in the laboratory of the Geological Survey, yielded the writer the following results:—

Silica, SiO_2	71.20
Alumina, Al_2O_3	15.46
Iron Sesqui-oxide, Fe_2O_3	1.17
Lime, CaO	1.36
Magnesia, MgO	0.33
Soda, Na_2O	4.96
Potash, K_2O	5.30
Ignition	0.52
Total	100.30

A comparison of the analysis of this rock with the analyses of the Lithonia granite-gneisses will reveal at once the practical identity of the two rocks. This analysis also closely resembles the analyses of the typical massive biotite granites; and each of the rocks carries the same minerals in relatively the same proportions. The only difference is in structure. All evidence points strongly to the area being one of metamorphosed granite, in which the original massive granite has, through the long continued and profoundly acting metamorphic forces or agencies, induced a secondary structure; and the rock is now a true granite-gneiss.

As stated above, numerous exposures of similar gneiss are found in Newton county; but none has been opened or worked. As viewed along the various wagon-roads, the residual decay, mostly deep red and lighter gray-colored clays, is usually deep, throughout the county.

CLARKE COUNTY

The only rock belonging to the granite type, that has been worked in Clarke county, is a coarse-grained, irregularly banded granite-gneiss, which can be used only for road and street purposes, and for rough masonry, such as retaining-walls, dams etc.

Two quarries, yielding identically the same grade of rock, have been operated, from time to time, in the eastern and the western limits of the city of Athens. A good supply of rock has been removed from both places and has been used mostly for street purposes in the above city.

A hand specimen of the rock, collected from the quarry on the east side of the city at the electric-light plant on the Oconee river, shows a very coarse-grained, dark-gray biotite granite-gneiss. A part of the biotite is arranged along parallel lines, and a part is thickly distributed through the rock without regard to orientation. The individual minerals composing the rock-mass measure from 5 to 15 millimeters in diameter. Large, porphyritically developed feldspar crystals (phenocrysts), measuring from 30 to 40 millimeters in length, with marked cleavage, and having biotite inclusions, occur. The biotite is present usually as large and stout plates, intimately associated with occasional muscovite folia, of equally large dimensions.

Under the microscope, a thin section of the rock, made from a hand specimen collected from the west-side quarry, reveals a distinctly coarse-granular rock, with the minerals interlocking in an intricate manner, and entirely without trace of rounded outline. It is composed of quartz and the feldspar species, orthoclase, microcline and plagioclase, with biotite and some intimately associated muscovite. The quartz and the feldspar species occur as large irregular interlocking grains, without crystal outline. Zonal structure is quite common to the feldspars, and the larger crystals contain enclosed rounded grains of quartz and of other feldspars. The plagioclase is altered to a much greater extent, than the potash species present in the rock. The biotite occurs as aggregated foils, of a brown color with strong absorption; and it is variously altered to a deep red, slightly pleochroic, and weak double-refracting chlorite. Numerous muscovite shreds are intergrown with the biotite. Occasional micropegmatitic intergrowths of quartz and feldspar are observed. Mechanical strain is manifested in small crushed areas of quartz and feldspar, and by lines of fracture, frequently filled with mineral matter.

A chemical analysis of this rock, yielded the writer the following results : —

Silica, SiO_2	69.51
Alumina, Al_2O_3	16.32
Iron Sesqui-oxide, Fe_2O_3	2.38
Lime, CaO	1.84
Magnesia, MgO	1.28
Soda, Na_2O	3.82
Potash, K_2O	3.47
Ignition	1.11
Total	99.73

The increase in the biotite content of this rock over those occurring in some of the other counties in Georgia, is not only apparent in the hand specimen; but it is brought out in the above analysis, where a corresponding increase is shown in the percentages of iron and magnesia.

Outcrops of a similar rock are extensively exposed in the cuts of the Seaboard Air Line railway, for several miles to the north and south of the depot in Athens. Also, at numerous places along the Oconee river, similar exposures are frequent.

MORGAN COUNTY

Only a few outcrops of workable granite have so far been located in Morgan county. The principal one is located on the north side of Hard Labor creek, approximately five miles northwest of Madison, the county-seat. The outcrop consists entirely of boulders, which vary in size from a few feet to eight or ten feet in diameter, scattered over a slight prominence. The Macon and Athens division of the Central of Georgia railway has been cut directly through the knoll; but, owing to the extreme depth in residual decay of the rock, it furnishes only a vague idea of the actual field conditions of the granite. The width of the zone, over which the granite boulders are scattered, is approximately 200 yards, sectioned along the railroad. As nearly as could be determined from the decayed material, the surrounding country-rock is a copper-colored mica gneiss and schist, carrying more or less muscovite in places. Some of the largest granite boulders have been worked up by the railroad, and used along its line.

In the hand specimen, the rock is a massive, fine-grained, even-granular, dark-gray biotite granite. It resembles very closely, in color, grain and texture, the rock of the Linch quarry in Putnam county.[1] In parts of the rock, not entirely fresh (partial decay), the feldspars have a decidedly pinkish cast.

Under the microscope, the rock appears as a fine-textured, allotriomorphic-granular granite, composed of an aggregate of complexly interlocking grains of quartz, and the feldspar species, orthoclase, plagioclase and some microcline, with biotite. The feldspars make up the greater percentage of the rock-mass, and are present with the usual characteristic optical properties. Microperthite is present in some amount, and biotite occurs as small shreds and foils, with the usual brown color and strong absorption.

A specimen of the much weathered, but hard and firm rock, indicates a ferruginous mass containing perfectly white, opaque and chalky feldspars, leached biotite folia, and quartz. An examination of a thin section of the weathered rock under the microscope shows, that, while some of the mica folia have suffered but little,

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[1] See page 166.

most of them have been almost wholly oxidized, accompanied by a subsequent leaching, which has resulted in staining the section a yellowish-brown color from the iron oxide liberated. The feldspars are badly broken down into kaolin, muscovite and calcite; but, as a rule, they are not affected by the atmospheric agencies to the extent of the biotite. It would appear, therefore, that the biotite in this rock is much more susceptible, than the feldspars, to the agencies of disintegration and decomposition.

Near the southwest boundary between Morgan and Greene counties, along a small stream, one mile southwest from Parks mill in the latter county, is an outcrop of coarse-grained biotite gneiss. The outcrop indicates, that the rock has but little value for economic purposes.

PUTNAM COUNTY

Putnam county is located near the central part of the State, joining Hancock county on the west, and is immediately north of the southern tier of counties in the Piedmont Plain crossed by the "fall line". While several areas of superior granite are known to occur in this county, no systematic quarrying has ever been attempted. Some rock, however, has been quarried near Eatonton, the county-seat, from time to time, for local use.

THE LINCH QUARRY.—This quarry is located four miles from Eatonton, a few degrees south of west, and three-quarters of a mile south, from its nearest point, to the Gordon, Milledgeville and Covington branch of the Central of Georgia railway. The rock begins to outcrop, along the Hillsboro wagon-road, approximately one mile east of the quarry. Numerous outcrops, within close proximity to each other, extend over the western hill-slope of Little river, several of which have been opened and some rock, quarried. Outcrops occur in the bed of Little river, to the north of the wagon-road leading west from Eatonton and northeast of the Linch quarry, where some rock was quarried by Messrs. Venable Brothers, of Atlanta, three years ago. Considerable variation is observed in the rock quarried from the river openings, when compared with the Linch granite. This is made clear in the description of the rock from the Marshall quarry given below, when compared with that of the Linch granite.

The main opening of the Linch quarry is in a ledge outcrop occurring along a small branch, tributary to Little river. Exposures of the rock are continuous up the tributary stream for some distance. So far as could be determined from the rock outcrops, the belt of granite is one mile long by from a half to three quarters of a mile wide. The rock is readily accessible, and can be easily worked. In the openings made, the rock is cut by a series of joint-planes, with slightly slickensided surfaces, occurring at such intervals as to facilitate the quarrying of large dimension stone. A few veins of quartz and feldspar, of slight width, occur; but they are by no means sufficiently numerous to in anywise damage the rock. The stone quarried has been used for monumental stock. Two other openings have been made close at hand, and a small quantity of the rock, quarried.

In the hand specimen, the rock appears as a massive, very fine, even and compact grained, dark blue-gray biotite-granite, of superior quality and free from all deteriorating substances. It resembles very closely a specimen of the "New Westerly" from Declezville, San Bernadino county, California, included in the 10th Census Collection of Building Stones, in the U. S. National Museum, Washington, D. C.

Under the microscope, a thin section of the rock indicates a fine-grained, allotriomorphic-granular granite, composed of the feldspar species, orthoclase, microcline and plagioclase, and quartz and biotite. An abundance of muscovite is present, associated always with the feldspar constituent, from which it was derived. It is, therefore, secondary in origin. The quartz, in rare instances, forms mozaics occupying well defined areas; but it usually occurs as single anhedra filling the feldspar interspaces. Orthoclase is greatly in excess of any other feldspar present. It occurs as very irregular grains, with microperthitic and zonal structures, and enclosing other feldspar species and small rounded grains of quartz. Microcline and plagioclase occur in their usual characteristic forms; but they are much less abundant than the orthoclase. The percentage of soda present in this rock would indicate, that the orthoclase was a soda variety and not the straight potash orthoclase. The feldspars are considerably altered, and their surfaces are largely covered with muscovite scales and shreds. Biotite is present as brown foils with strong absorption, intimately associated with occasional shreds of primary muscovite. It is variously altered to chlorite and large irregular crystals of epidote. Microscopic inclusions of apatite and zircon occur, along with scattered grains of the iron oxide, magnetite.

A chemical analysis of this rock, made in the Survey laboratory, yielded the writer the following results:—

Silica, SiO_2	69.34
Alumina, Al_2O_3	17.01
Iron Sesqui-oxide, Fe_2O_3	1.74
Lime, CaO	2.77
Magnesia, MgO	0.61
Soda, Na_2O	4.69
Potash, K_2O	4.54
Ignition	0.26
Total	100.96

Specific Gravity	2.701
Weight of one cubic foot of stone expressed in pounds	168.81
Number of cubic feet of stone contained in one ton (2,000 pounds)	11.8
Percentage (ratio) of absorption	0.060

The weathered product (sap), still hard and firm rock, consists of a rusty colored mass, in which the feldspars are dull, opaque and highly kaolinized; and the biotite, partially oxidized and decomposed, yielding a ferric staining, which colors the partially decayed rock a yellowish-brown, rusty color.

An 8-inch cube of the rock from the Linch quarry, hammer-dressed and polished, is on exhibition in the State Museum, in the Capitol building. The specimen shows a strong contrast in color between the hammered and polished faces, and a very high, even and smooth polish, which, when added to its other good qualities, renders it a very desirable monumental stone.

THE MARSHALL PROPERTY.—That portion of the granite outcropping along and in the bed of Little river, near the point, where the stream is crossed by the Central of Georgia railway, forms a part of the Marshall estate. Messrs. Venable Brothers, of Atlanta, quarried some rock in the stream-bed for fortification work three years ago, on a lease from Mrs. Marshall. An examination of a large boulder, which had been partially worked up on the west bank of the stream and just off the wagon-road, revealed a fine-grained, light-gray biotite-granite, with a distinctly laminated or foliated structure.

Microscopic study of a thin section of this rock (Museum No. 1,880) reveals a granite, composed of the feldspars, orthoclase, plagioclase and microcline, and quartz and biotite, complexly interlocked. While the laminated structure is definitely marked in the hand specimen, it is not at all apparent under the microscope. The orthoclase and microcline are present in the usual proportions, and display the characteristic optical properties. Plagioclase is somewhat more abundant than usual, and is present as stout laths, with broad and distinct lamellæ, and with considerable variation in the extinction angles, which probably indicates the presence of several plagioclase species. The larger feldspar crystals enclose rounded

FIG. 1. PHOTO-MICROGRAPH OF HORNBLENDE-SCHIST (AMPHIBOLITE), CONTAINING MUCH EPIDOTE. FOUR MILES SOUTHEAST OF LAWRENCEVILLE, GWINNETT COUNTY, GEORGIA.
Crossed Nicols x 74.

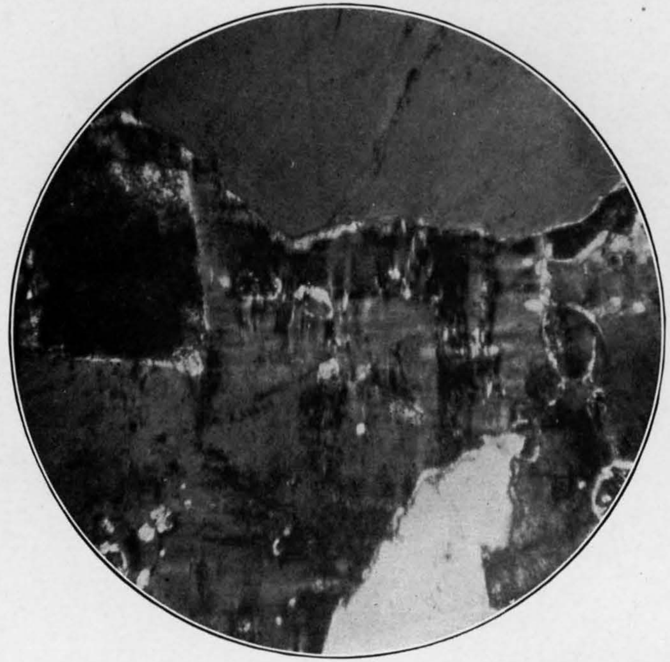


FIG. 2. PHOTO-MICROGRAPH OF THE PORPHYRITIC GRANITE FROM THE GEORGIA QUINCY GRANITE COMPANY'S QUARRY, TWO MILES EAST OF SPARTA, HANCOCK COUNTY, GEORGIA.
Crossed Nicols x 74.

grains of quartz. The orthoclase usually shows considerable microperthitic structure. The quartz occurs as well defined mozaics and as single anhedra, filling the feldspar interspaces. Biotite is present as thin foils with the usual color and absorption, and is considerably altered to epidote and some chlorite. Scattered grains of magnetite and inclusions of zircon occur.

This rock differs microscopically from that occurring at the Linch quarry, in carrying a greater amount of the feldspars, microcline and plagioclase, and a proportionally smaller amount of the black mica, biotite. It differs, macroscopically, in being lighter in color and laminated, instead of massive, in structure.

The residual decay of this granite is well shown in sections of considerable depth at several places along the wagon-road, the final limit in the decay of which has apparently been reached, where a stiff, red clay occurs as the decomposed product.

THE FLAT ROCK EXPOSURE.—An extensive flat-surface outcrop of a fine-grained biotite-granite, badly sheared, and cut up by pegmatitic veins and dikes, occurs at Armour's mill, eight miles southeast of Eatonton. Baptizing creek, which furnishes the power for a grist-mill just beyond the granite exposure, flows directly over the main outcrop of the rock. The rock exposed at this point can be used only for street work and rough masonry; as it is too badly sheared and cut up by veins and dikes, to be used as a building or monumental stone. The outcrop is approximately one and a half miles southeast from the nearest railroad point. The same rock outcrops at several points on the old Steve Marshall place as flat, dome-shaped masses, of small dimensions. At each of the above outcrops, the rock is characterized by the laminated structure cut by veins and dikes.

Under the microscope, a thin section of this rock (Museum No. 1,881) indicates a very fine-grained, foliated or laminated granite, composed of quartz and the feldspar species, orthoclase, microcline and plagioclase, with biotite and a slight sprinkling of hornblende as the ferro-magnesian accessory minerals. The potash feldspar varieties are present in excess over the plagioclase. The quartz has its usual development and occurrence. The biotite occurs as thin foils with brown color and strong absorption, and is arranged along somewhat definite parallel lines. It is in part altered to chlorite. Numerous green colored allotriomorphic grains of hornblende, with strong absorption and marked cleavage, are associated with the biotite. Large and small pleochroic grains of epidote, without crystal outline, are rather abundant.

This rock closely resembles some of the fine-grained dark-colored granites from other sections of the State; but it differs from them mainly in being highly laminated in structure, and hornblende-bearing.

BALDWIN COUNTY

Baldwin county lies to the west of Hancock and to the south of Putnam, with the Crystalline rocks of its southern portion overlain by the Coastal Plain sands and clays. Several areas of granitic rock occur in this county to the north of and near the line of contact between the Piedmont crystallines and the Coastal Plain sediments; but no quarrying has been done, save the getting out of a few stones, from time to time, for local use.

MRS. L. N. CALLOWAY'S PROPERTY. — Three miles southeast from Milledgeville on the northeast side of the public wagon-road, are extensive outcrops of immense boulder masses of a coarse-grained, porphyritic granite, along each side of a small stream. An examination of the rock in the field disclosed large porphyritic feldspar crystals, 30 to 40 millimeters (about 1½ inches) long, of a slight pinkish cast, embedded in a coarse-grained groundmass. It is said, that some of the granite used in the old State Capitol building at Milledgeville, now used for the State Normal and Industrial College, came from this locality. No opening was found by the writer, where the rock had been quarried; but an examination of the rock in the building and in the field proves the two to be the same.

Hand specimens of this rock can not be distinguished from similar specimens of the Heggie rock in Columbia county, which represents that portion of the mass characterized by a gray instead of a pink colored groundmass, and containing nearly white, porphyritic feldspar crystals. The rock is a very coarse-grained, porphyritic, dark-gray biotite granite. The porphyritic feldspar consists of both orthoclase and microcline, which occur as white, opaque and highly lustrous crystals, tabular parallel to the clinapinacoid (010), with good development of cleavage parallel to the base (001) and the clinopinacoid (010), and twinned according to the Carlsbad law. The phenocrysts measure, in extreme cases, 30 to 40 millimeters long and 5 to 10 millimeters broad. The groundmass is composed of an abundance of white, opaque feldspar; slightly dark, vitreous quartz; and plates of black biotite. These minerals will measure from 2 to 5 millimeters in their longest directions. Enclosed plates of biotite occur in the feldspar phenocrysts.

A microscopic examination reveals the presence of quartz and the feldspar species, orthoclase with microperthitic structure, microcline and plagioclase, and intergrown shreds of biotite. Both orthoclase and microcline occur in the groundmass, and as porphyritically developed minerals. Twinning, according to the various laws common to the feldspar species, is frequent. Zonal structure in the feldspars is also common. Enclosures of biotite, quartz and feldspar grains, of irregular outline, occur in the feldspar phenocrysts. Extremely fine and long, straight and curved needles of rutile are very abundant, as inclusions in some of the quartz anhedra. An abundance of secondary muscovite and kaolin occur as a result of feldspathic decay. A few scattered grains of magnetite are seen in the thin section under the microscope. Planes of fracture, indicative of mechanical strain, are numerons in the quartz and feldspars.

A chemical analysis of the rock, made in the Survey laboratory, yielded the writer the following results: —

Silica, SiO_2	69.37
Alumina, Al_2O_3	16.99
Iron Sesqui-oxide, Fe_2O_3	1.99
Lime, CaO	2.03
Magnesia, MgO	0.84
Soda, Na_2O	3.44
Potash, K_2O	4.54
Ignition	0.55
Total	99.75

A comparison of this, with analyses of porphyritic granite from Columbia, Greene, Fayette and Coweta counties, shows a marked similarity. A weighed portion of the finely powdered fresh rock, digested for three hours in boiling half-normal hydrochloric acid, gave 11.79 per cent. of soluble matter.

Weathering. — It was generally observed in the field, that, in the weathering of this rock, the feldspar phenocrysts offered greater resistance to the disintegrating and decomposing agents than the groundmass, invariably resulting in the phenocrysts standing out a small fraction of an inch above the general surface of the rock. While these were always more or less cloudy and opaque from kaolinization, they frequently displayed brilliant lustre along the cleavage faces. The process of weathering is carried forward by the decomposition of the biotite, with a discoloration derived from the oxidation and leaching of the iron oxide, and the kaolinization of the feldspar, revealed in the dullness and opacity of the surfaces, resulting in the formation of a white, chalky material, kaolin. Disintegration, also, plays equally as prominent a part, if not greater, in the early weathering of the rock. It is manifested in the splitting up of the feldspars and mica along the planes of cleavage, especially the feldspar phenocrysts into smaller particles. The mechanical forces open up the way for the action of the chemical agents. The rock crumbles by this means into a coarse-grained granitic sand.

The old State Capitol building at Milledgeville was erected in the early twenties of the century just ended; and the pieces of this rock used in the structure, remain almost, if not quite, as fresh, as on the day they were put into the building. No discoloration of any kind is visible, and the larger phenocrysts of feldspar reflect their brilliant lustre for a number of paces away. These observations were made on polished surfaces of the rock used as trimmings in the building.

GRANO-DIORITE

About half way between Milledgeville and the State Sanitarium, along a small branch, crossing the main driveway, are boulder outcrops of a dark-blue rock, which has been used to some extent for street purposes in the town of Milledgeville, and which is known to the citizens as "blue granite." A large part of the area between the town and the Sanitarium includes exposures of this rock, seen along the various roads crossing the belt and in the gulches and ravines found dissecting the area. The rock weathers to a black clayey mass, more the result of mechanical than of chemical forces.

In the hand specimen, the rock is fine-grained, decidedly schistose in structure, and of a dark blue-gray color, which on close examination is seen to be speckled with small patches of white feldspar scattered through it, and mixed with the dark-blue, ferromagnesian minerals. The speckled appearance is best seen on fractured surfaces made at angles to the planes of schistosity. In places, the rock is more or less porphyritic, with phenocrysts of perfectly white feldspar, without distinct crystal form, distributed sparingly through the rock. Several of the phenocrysts measured an inch and more in length; but usually they were not more than 5 to 10 millimeters long.

In the hand specimen, the feldspars are usually readily distinguished from the other minerals by their highly lustrous cleavage faces.

Microscopically, the rock consists of hornblende, biotite, lime-soda feldspar, orthoclase, quartz, epidote, magnetite, chlorite and inclusions of apatite. Of these, hornblende, biotite and plagioclase are the most abundant. The plagioclases are more nearly idiomorphic than the other constituents, and are usually lath-shaped in outline; but they are not entirely so. Orthoclase is present as single cleavable grains, and surrounds the crystals of plagioclase as a well defined border with irregular outline. The quartz forms the irregular grains between the other minerals. The outlines of the hornblende and biotite are usually very irregular, and they penetrate one another in a most complex manner. Magnetite is present to some extent, as enclosed irregular grains, in the ferro-magnesian minerals. Epidote, of a brownish-yellow color, occurs as large, irregular, slightly pleochroic grains, with high double-refraction. The plagioclase exhibits the characteristic polysynthetic twinning, and at times, zonal structure. In thin section, the biotite is dark-brown in color, with good cleavage, strong absorption and irregular outline. It is partly enclosed by the hornblende, in some cases; though, usually, it is separated from, and on the outside of this mineral. The hornblende is in part green, and in part brown, the latter being sometimes within the former. Parting, parallel to the longitudinal direction, is most commonly observed; although numerous grains, showing prismatic cleavage, and making angles of 120° with each other, are frequently seen. The average maximum extinction angle, measured on a number of grains, gave 19°, ranging between 16° and 20°.

The chemical composition of this rock, as determined by the writer, is given in the following analysis: —

Silica, SiO_2	55.47
Alumina, Al_2O_3	22.63
Iron Sesqui-oxide, Fe_2O_3	3.96
Lime, CaO	6.62
Magnesia, MgO	2.97
Soda, Na_2O	4.59
Potash, K_2O	2.09
Ignition	0.69
Total	99 02

While this rock is locally known as granite, it is not a true granite, as may be readily seen from the description and analysis above.

Other outcrops of granite occur in Baldwin county at the following points: One along the Oconee river, some seven or more miles from Milledgeville, and another, one and a half miles west of Carr's station on the west side of the Macon branch of the Georgia railroad.

HANCOCK COUNTY

Hancock county is bounded on the east by Warren county, and on the northwest, west and southwest, by Greene, Putnam and Baldwin counties, respectively, the surface of its southern portion consisting of Coastal Plain sands and clays. More or less extensive areas of granitic masses are found; and in some cases, they are worked to a limited degree, in each of the above named counties bounding Hancock. The worked areas of granite in Hancock are grouped on the east and northeast sides of Sparta, the county-seat, and occupy the middle section of the county, lying principally along the Macon & Augusta division of the Georgia railroad. Beginning about a quarter of a mile east from the Sparta depot, on the south side of the Sparta-Culverton wagon-road, the rock outcrops more or less continuously for eleven miles from this point, in a slightly northeast direction along the railroad, to within a quarter of a mile of Mayfield station near the Warren-Hancock county-line. While no outcrops of the fresh rock are visible, the residual decay, exposed in the railroad cut at, and to the west of, the Sparta depot, affords abundant evidence of its having been derived from the granite. Boulder outcrops of the same granite are in evidence at several points along the railroad, to the westward, between Sparta and Milledgeville, thus indicating a westward as well as an eastward extension of the granite area.

As may be seen from the description of the individual properties below, the rock occurring in this county, is not a true, even-grained granite; but, on the contrary, it represents, over the greater portion of the area, a porphyritic facies of the granite magma, and is therefore a porphyritic granite.

THE CHARLEY ROCKER QUARRY. — This quarry is located approximately three and a half miles northeast from Sparta, on the north side of, and about three quarters of a mile from, the Georgia railroad, and is known as the New Rocker quarry. This quarry was recently worked by The Georgia Quincy Granite Co., of Macon, Georgia, under lease from the owner, Mr. Charles Rocker. The rock outcrops as flat surfaces over an area of probably half-a-dozen acres. It has been extensively worked, a large amount of stone having been quarried. As many as three or four "raises" in superposition have been made, in some portions of the quarry; while, in others, nothing more than the top or "natural raise" has been stripped off. The quarry is capable of yielding a large supply of excellent stone. It is easily worked, and is readily accessible to the railroad. The rock quarried has been used principally for street purposes, mostly in the form of Belgian blocks.

Megascopically, the rock is a coarse-grained porphyritic biotite granite, presenting a partial gneissoid structure in places, in addition to the porphyritic texture. The component minerals, quartz, feldspar and biotite, are readily differentiated by the unaided eye. The porphyritic feldspar, orthoclase, varies from an irregular, somewhat rounded individual to large prismatic tabular crystals, measuring 20 mm. in length and 8 to 10 mm. in width. The cleavages, (001) parallel to the base and (010) parallel to the clinopinacoid, are strongly developed. The phenocrysts of orthoclase are twinned after the simple type of Carlsbad twins.

The rock is light gray in color. The feldspars are prevailingly white and opaque, sometimes translucent, and, at times, tinged a distinct pinkish hue; and they display a marked pearly lustre on the cleavage faces. The porphyritic crystals of orthoclase are embedded in a coarse-grained, light-gray groundmass of quartz, feldspar and biotite. The quartz anhedra are of a dark, smoky color, having a decidedly vitreous or glassy lustre. They measure, in extreme cases, from 5 to 6 mm. in the direction of their longer axis. The porphyritic constituent makes up as much as from a quarter to a half of the entire rock-mass.

Microscopic study of a thin section of this rock reveals a coarse-grained groundmass, composed of quartz and soda-lime (plagioclase) and potash (orthoclase) feldspars, in which lie stout shreds of biotite. No microcline was observed under the microscope. Some of the phenocrysts are decidedly microperthitic in their structure, and contain inclusions of all the groundmass minerals, especially plagioclase, in which the twinning lamellæ are well marked. The plagioclase is present as small lath-shaped grains, without perfect crystal outline. The extinction angles indicate a variety near oligoclase, as the plagioclase present. The biotite is present as somewhat stout plates, more or less altered to a dark opaque chlorite. Micropegmatitic intergrowths of quartz and feldspar occur in the groundmass. A few small scattered grains of magnetite and numerous prismatic needle-like inclusions of apatite are present in the orthoclase.

A chemical analysis of this rock in the Survey laboratory yielded the writer the following results: —

Silica, SiO_2	67.62
Alumina, Al_2O_3	16.29
Iron Sesqui-oxide, Fe_2O_3	2.31
Lime, CaO	2.37
Magnesia, MgO	0.78
Soda, Na_2O	5.42
Potash, K_2O	4.58
Ignition	.32
Total	99.69

The above analysis shows a slightly lower percentage of silica, and a corresponding increase in the iron and soda contents over those in the true granites of Elbert and Oglethorpe counties; although it is remarkably similar as a whole to the analyses of the rocks from the above counties. The increase of soda over potash, and the relatively high percentage of lime would indicate the presence of albite and soda-lime feldspar, as brought out in the microscopic study.

Other tests made on specimens of this rock gave the following figures: —

Specific Gravity	2.687
Weight of one cubic foot of stone expressed in pounds	167.93
Number of cubic feet of stone contained in one ton (2,000 pounds)	11.9
Percentage (ratio) of absorption.	0.037

It will be observed from the above figures, that the absorptive power of this rock is very low.

THE OLD ROCKER QUARRY. — This quarry was first known as the Charley Rocker quarry, and was one of the first in the county to be opened. It was controlled by Messrs. Carling, Hertz & Company, of Macon, and subsequently by THE GEORGIA QUINCY GRANITE COMPANY, of which Mr. T. E. Artope, of Macon, is general manager. It is located about a quarter of a mile northwest from the "New" Charley Rocker quarry described above, and is on the north side of, and half-a-mile from, the Georgia railroad. The exposed rock occurs in ledge form over several acres. Considerable work has been done; and the rock quarried has been used as Belgian blocks and curbing for street purposes. Several raises of varying thickness have been made, and the stone has been worked up.

The rock is a hard, firm, coarse-grained, light-colored granite, carrying a smaller amount of biotite, than that from the new Rocker quarry. It is composed principally of a coarse-grained, dark-smoky, vitreous quartz, with white to slightly pinkish opaque feldspar, and a few rather large, stout plates of black biotite. The texture is distinctly granitic-granular, as contrasted with the porphyritic texture of the new Rocker quarry, and represents the true granite facies of the magma. The differentiation, as regards texture for the two localities, is very marked for so short a distance.

Under the microscope, the rock consists of anhedra of quartz and feldspar firmly interlocked, with some biotite partially altered to chlorite and epidote. The feldspars present are microcline, microperthitic orthoclase, and a plagioclase near oligoclase. As contrasted with the new Rocker quarry, microcline is very abundant, the feldspar being the most abundant mineral present, with quartz next. So little biotite is present, that the rock can almost be grouped as a binary-alkali granite.

The stone is an excellent one; and is practically free from imperfections and blemishes.

THE GEORGIA QUINCY GRANITE COMPANY'S NEW QUARRY. — The property, on which this rock occurs, is owned by Mr. Lee,

THE GEORGIA QUINCY GRANITE COMPANY'S QUARRY, IN A FLAT-SURFACE OUTCROP OF PORPHYRITIC GRANITE, NEAR SPARTA, GEORGIA, ON THE MACON BRANCH OF THE GEORGIA RAILROAD.

recently of Covington, Georgia. The quarry is worked by THE GEORGIA QUINCY GRANITE COMPANY, under lease, with headquarters in Macon. Mr. Lewis A. Wood is President, and Mr. T. E. Artope, General Manager, of the company. The quarry is located about two miles northeast from Sparta, on the south side of, and half-a-mile from, the Georgia railroad, and one and a half miles south of the Rocker quarry. A side track, which provides ample facilities for shipping, is operated by the company from the Georgia railroad to the quarry. The rock outcrops as flat-surface or sheet exposures over approximately eight acres of surface. The first "raise" was being worked at the time of the writer's visit, and the work done extended over at least three acres. A large working force was employed, and the stone was worked mostly into Belgian blocks and curbing for street use; although a small percentage of it had been used in buildings and for monuments. The product was shipped to Tampa, Florida, and Macon, Georgia.

The rock is a coarse-grained, medium-gray, porphyritic biotite granite, with a slight tendency, in places, to a gneissoid structure, due to an imperfect arrangement of the biotite along roughly parallel lines, and a partial tendency toward orientation of the feldspar phenocrysts. Hand specimens of this and the new Charley Rocker quarry rock cannot be distinguished from each other. The phenocrysts of orthoclase are large, white-opaque and highly lustrous crystals, 15 to 20 mm. in diameter, generally tabular parallel to the clinopinacoid (010), and commonly twinned according to the Carlsbad law. These are, as in the former case, embedded in a coarse-grained, dark-gray groundmass of quartz, feldspar and biotite. The feldspars have usually a slightly pinkish cast.

Joint-planes, more or less slickensided along their surfaces, and a few veins of pegmatite, several inches in width, composed chiefly of large crystals of highly cleavable, white and pink opaque feldspar, through which are scattered large plates of black biotite, cut the granite mass.

Under the microscope, the rock consists of a coarse-grained quartz-feldspar-biotite groundmass, with porphyritically developed crystals of orthoclase and microcline. The quartz anhedra are generally small, though approaching at times that of the feldspar phenocrysts in size. The feldspar constituent consists of orthoclase, microcline and plagioclase, near oligoclase. The orthoclase is present as larger tabular phenocrysts, and smaller irregular grains in the groundmass, intergrown in part with a second feldspar, albite, as microperthitic structure. Microcline only appears as large porphyritic crystals, showing the characteristic twinned structure (gridiron). Plagioclase is rather abundant in the groundmass, as well defined, stout and slender laths, usually marked by the characteristic polysynthetic twinning. The species, oligoclase, with probably some albite, is strongly indicated, from measurements of the extinction angles on a number of the crystals. This is confirmed in the chemical analysis below. Biotite is the chief accessory mineral. It is present in the groundmass, only as plates and shreds of small size, with good cleavage and strong absorption, and is altered in part to chlorite and some epidote. Occasional shreds of muscovite are intergrown with the biotite.

A chemical analysis of specimens of the rock yielded the writer, in the Survey laboratory, the following results: —

Silica, SiO_2	70.90
Alumina, Al_2O_3	15.86
Iron Sesqui-oxide, Fe_2O_3	1.37
Lime, CaO	2.15
Magnesia, MgO	0.02
Soda, Na_2O	5.05
Potash, K_2O	4.62
Ignition	0.50
Total	100.47

Other tests made were as follows: —

Specific Gravity	2 664
Weight of one cubic foot of stone expressed in pounds	166.50
Number of cubic feet of stone contained in one ton (2,000 pounds)	12.0

This, as well as the Rocker quarry granite, is remarkably uniform; and both are absolutely free from impurities likely to cause staining or discoloration on exposure. It is easily worked, and is well adapted for building and street purposes.

THE MALLALLY GRANITE QUARRY. — This quarry was worked and controlled by THE GEORGIA QUINCY GRANITE COMPANY. It is located about three quarters of a mile northeast from Sparta, on the north side of, and about a quarter of a mile from, the Georgia railroad. A side-track was in operation at the time of working, from the Georgia railroad to the quarry. No work has been done for some time. About two acres of flat-surface outcrops occur, in which several "raises," of varying thickness in superposition, have been made. The quarry had been worked to a considerable depth in several places, and the openings were almost completely filled with water, at the time of the writer's visit. A few spots of rather large biotite segregations were observed in several places through the rock; but these are by no means common, and do not affect the quality of the stone. Some jointing with an east-west direction occurs. A dike of very fine-grained, dark blue-gray biotite granite, slightly porphyritic near the contact, and several feet in width, cuts the porphyritic granite mass.

The rock can hardly be distinguished in the hand specimen from that worked by THE GEORGIA QUINCY GRANITE COMPANY on the Lee property. It has perhaps less porphyritic tendency, and contains a slightly larger amount of the flesh-colored feldspar.

It is a coarse-grained, medium-gray, porphyritic biotite granite, in which the component minerals are readily recognized macroscopically. The porphyritic feldspar is about evenly divided between the irregular single individuals, and the flat, tabular[1] crystals, twinned according to the Carlsbad law. The feldspars are white-opaque and flesh-colored.

Under the microscope, the rock is composed of a coarse-grained groundmass of quartz, feldspar and biotite, with phenocrysts of orthoclase embedded therein. The quartz is present as both small and large, irregularly bounded grains, of the dark-smoky variety. The feldspathic constituent consists of microperthitic orthoclase with microcline and plagioclase. Twinning of the feldspars, according to the several laws, is characteristic of the various species. Biotite, as small plates with good cleavage, deep color and strong absorption, variously altered to chlorite and epidote, is present as the chief accessory. Sparse intergrowths of muscovite with biotite occur. Micropegmatitic intergrowths of quartz and feldspar are very common.

A chemical analysis of the rock from the Sparta quarry yielded the writer the following results: —

Silica, SiO_2	69.48
Alumina, Al_2O_3	16.64
Iron Sesqui-oxide, Fe_2O_3	1.84
Lime, CaO	2.32
Magnesia, MgO	0.29
Soda, Na_2O	4.74
Potash, K_2O	4.49
Ignition	0.46
Total	100.26

A total of 10.81 per cent. of soluble matter was extracted from a weighed quantity of finely pulverized rock, after digestion for three hours in boiling half-normal hydrochloric acid.

Absorption tests made on specimens of this rock gave the following figures: —

Percentage (ratio) of absorption	0.049

The figures indicate a minimum absorption for this rock. The rock quarried has been used mostly for monumental stock.

[1] Tabular in the direction of the clinopinacoid (010).

THE MACKIN PROPERTY. — This property contains some three or four acres of flat-surface outcrops, exposed in one mass, and located from one and three-quarters to two miles northeast of Sparta, and about half-a-mile from, and on the north side of, the Georgia railroad. Two months previous to the writer's visit, one small opening was made in the outcrop, revealing a coarse-grained porphyritic granite, carrying an abundance of feldspar. A dike of very fine and even-grained biotite granite, nine feet in width, cuts the porphyritic mass, and is well exposed in the opening. The rock of the porphyritic mass is, in all respects, the same as that quarried at the Sparta quarry, with the exception that the feldspars are somewhat deeper in color, and more prevailingly pink or flesh-colored. In the rock from the quarries in this county, hitherto described, the feldspar phenocrysts are usually white and opaque; while they are prevailingly pink from the Mackin place.

The pink, tabular phenocrysts are from 15 to 20 millimeters long, parallel to the clinopinacoidal direction, and are twinned according to the Carlsbad law. They are embedded in a coarse-grained groundmass, of light-gray color, composed of quartz, feldspar and biotite. The dark, smoky quartz grains stand out in strong contrast with the pink feldspar and the black, shining biotite; and, in extreme cases, they measure from 6 to 8 mm. in length. The larger feldspar grains show marked cleavage in two directions. The biotite rarely exceeds 3 or 4 mm. in diameter.

An unlimited supply of excellent stone can be obtained from this body of rock. In April, 1901, Mr. Mackin opened a second quarry, half-a-mile southwest from the Georgia Quincy Granite Company's quarry on the south side of the Georgia railroad. The property was leased by Mr. Mackin from Mr. W. B. Lee, of Sparta, Georgia. It is estimated, that about 300 carloads of the stone have been removed from this opening. The rock has been used principally for street work and buildings in Macon and Augusta. This is the same rock as that quarried at the Georgia Quincy Granite Company's quarry, described above.

RÉSUMÉ

As described above, the Hancock granite area is approximately eleven miles in length, and lies in a slightly north of east direction along the Macon and Augusta branch of the Georgia railroad, extending from the Sparta depot to Mayfield station near the county-line between Warren and Hancock counties. It outcrops as boulders and flat-surface masses, containing as much as four or five acres of exposed rock in one body, at numerous points. It is prevailingly a coarse-grained, medium-gray, porphyritic biotite granite, composed of white-opaque and flesh-colored orthoclase, and some microcline, phenocrysts, embedded in a coarse-grained groundmass of quartz, feldspar (orthoclase, microcline and plagioclase) and black biotite. The phenocrysts are tabular in form, the largest averaging 20 mm. long, in the direction of the clinopinacoidal plane (010). They show good cleavages, parallel to the basal pinacoid (001) and the clinopinacoid (010). The quartz grains, which are distinctly allotriomorphic, are of the dark-smoky, glassy variety, and measure from 6 to 8mm. in length. The biotite occurs as stout plates, from 3 to 5 mm. in width; is highly cleavable and lustrous; and varies in amount according to locality. The order of quantative occurrence of the component minerals is feldspar, including all species present, > quartz > biotite.

In several places, the porphyritic facies almost wholly disappears, and the rock grades into a coarse-grained biotite granite. The porphyritically developed feldspar is further characterized by numerous inclusions of all the groundmass minerals.

Chemically, the porphyritic granites are identical with, and show practically no variation from, the true granites occurring in other counties. They contain the same minerals in approximately the same relative proportions. The following analyses of samples of granite from various Hancock county quarries were made by the writer in the Survey laboratory:—

	I	II	III
Silica, SiO_2	67.62	69.48	70.90
Alumina, Al_2O_3	16.29	16.64	15.86
Iron Sesqui-oxide, Fe_2O_3	2.31	1.84	1.37
Lime, CaO	2.37	2.32	2.15
Magnesia, MgO	0.78	0.29	0.02
Soda, Na_2O	5.42	4.74	5.05
Potash, K_2O	4.58	4.49	4.62
Ignition	0.32	0.46	0.50
Total	99.69	100.26	100.47

I The Charley Rocker quarry.
II The Sparta quarry.
III The Georgia Quincy Granite Company's quarry.

A comparison of these analyses with those of the true granites from Elbert and Oglethorpe counties shows very close agreement.

Absorption tests, made on two specimens of rock from quarries somewhat widely separated in this belt, gave the following results:—

I Percentage (ratio) of absorption	0.049
II Percentage (ratio) of absorption	0.037

The figures indicate granites with a minimum absorption. They are, therefore, not appreciably affected by frost action.

Weathering. — An outcrop of the rock, two miles northeast from Sparta, crossing the Sparta-Culverton wagon-road, indicates kaolinization of the feldspars and granulation, or falling to pieces, of the rock, from disintegration by the various mechanical forces, into a coarse, yellow sand. The sand consists of quartz and kaolinized feldspar grains, with scattered and partially leached biotite folia.

Uses. — Up to the present, the rock quarried has been used principally for street purposes, in the form of Belgian blocks and curbing. A small percentage, however, has been used in buildings and for monuments.

The surrounding country-rock is mica-schist, a large body of which occurs from a quarter to half-a-mile from Sparta, on the west side, the main body of granites lying to the east. The depth of residual decay renders exposures of the contact between the two rocks impossible; but general field relationships indicate, that the porphyritic magma was intruded into the schist, and is, therefore, younger in age than the latter.

GREENE COUNTY

Greene county lies immediately south of Oglethorpe county and north of Hancock. Rather numerous and somewhat extensive outcrops of granite occur in various places through the county; but no quarries have yet been worked, although some stone for local use has been stripped from the surface of several of the outcrops. The most extensive area is found some distance from the railroad, which probably accounts, in large measure, for the granite's not having been worked. The central mass is a typical porphyritic granite, of excellent quality.

The Wright Property. — One mile northeast from Greensboro, on the south side of, and a few hundred yards from, the Georgia railroad, on a 10-acre lot owned by Mr. J. W. Wright, are outcrops of a coarse-grained, binary-alkali granite. The rock is exposed on Mr. Wright's place, in the form of flat surfaces, with numerous outcrops of the same rock occurring on the adjacent properties; but no opening has yet been made.

In the hand specimen, the rock is a medium-coarse, but even-grained, light-gray granite, composed of approximately equal proportions of opaque-white and slightly pinkish feldspars, displaying good cleavage and lustre, in some cases; and black, smoky, highly vitreous quartz grains, with occasional scattered plates of muscovite and biotite. The quartz and feldspar grains measure from 4 to 6 mm. in diameter, in the case of the largest grain. The rock is, from all appearances, a distinct binary granite, in which mica is essentially absent. The color and lustre of the quartz grains offer a ready means of distinction from the feldspars, from which they stand out in marked contrast.

Along the wagon-road, within a few paces of the railroad, is a fairly good section of the weathered rock in natural outcrop. It weathers in layers, varying from many inches to a foot and more in thickness, imparting a gneissoid or layer structure. The process of weathering is mainly one of granulation, through hydration and temperature changes, whereby the feldspars are split along the cleavage planes and kaolinized. The slight amount of mica present is broken down by oxidation, and the rock is stained a rusty color from the iron oxide leached therefrom.

THE PORPHYRITIC GRANITE AREA

About ten miles south from Greensboro, the county-seat, is an extensive body of porphyritic granite, comprising at least 100 acres of outcrop in all. The outcrop is in the form of a low, flat, dome-shaped mass, made up of isolated knolls or peaks, with partially connecting sheets.[1] Mr. W. R. Jackson owns about half of the main granite mass. The rock outcrops more or less continuously along the Greensboro-Sparta wagon-road, for a distance of a mile and more to the northwest of the main mass. Thence, along the same road in a northwest direction, a zone of approximately one mile in width is traversed, where no outcrops of any kind are found. Thence, two and a half miles north from the main outcrop of porphyritic granite along the same road, are outcrops of a medium-grained biotite granite, showing no tendency to porphyritic structure whatsoever. On the same road, five miles slightly east of south from Greensboro, at Veazy's store, are outcrops of a coarse- but close-grained granite, the feldspars of which have a decidedly pinkish color. The rock carries but little mica.

Another outcrop of the same granite is seen on the north side of a stream near the store. About four miles southeast from Greensboro, along the same road and on the north side of Beaver Dam creek, is an outcrop of practically the same granite; but the quartz in it is of a smoky variety, decidedly dark in color. But little mica is present, and the feldspar is flesh-colored. The outcrops of

[1] See Plate XVII, Fig. 1.

this rock are more or less continuous along the wagon-road, to within several miles a little east of south of Greensboro. After leaving the main outcrop of the porphyritic granite and travelling towards Greensboro, the outcrops are invariably of the boulder type, usually of extraordinary dimensions.[1]

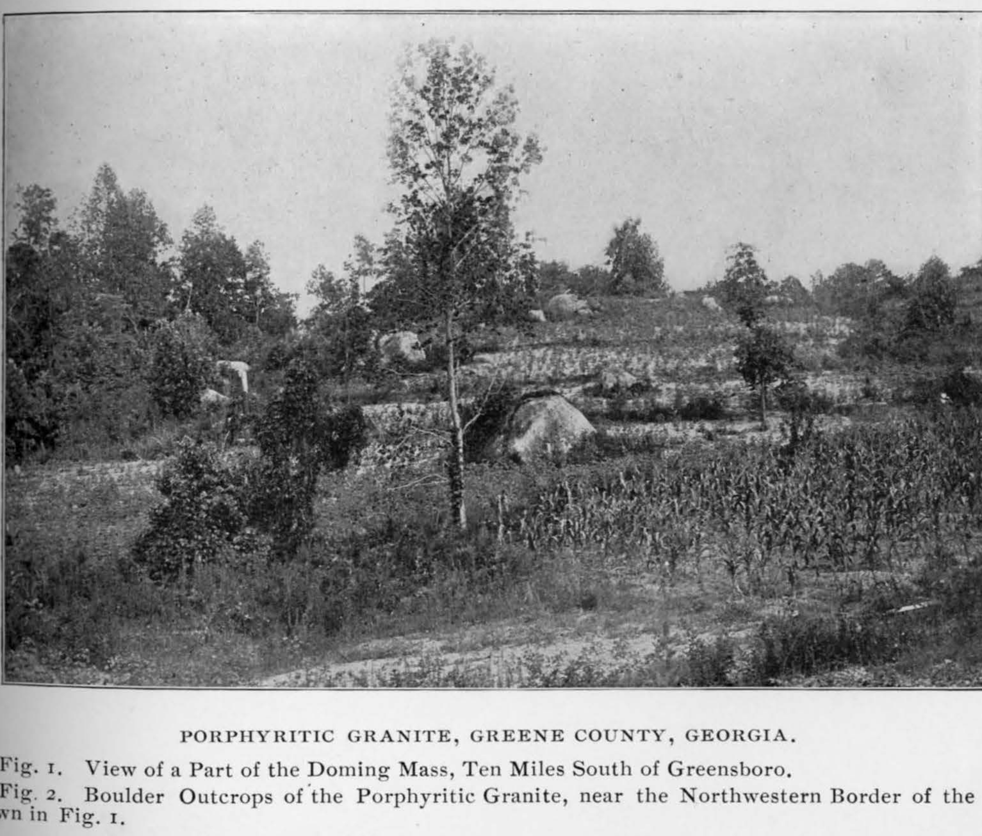
Owing to a lack of fresh granite exposures, from the extreme depth of covering of the residual rock decay, the exact relationship between the two granite facies could not be worked out in the field. The nearest exposures of the porphyritic and non-porphyritic, or even-granular, granite to each other showed no appreciable gradation from one to the other. While the necessary exposures are lacking, there can scarcely be any doubt, as to the two facies representing the same granite-mass, with the central portion, porphyritically developed, grading peripherally into an even-grained granite, of the same mineral and chemical composition. As is shown below, the feldspar phenocrysts carry inclusions of the groundmass minerals, which proves that the porphyritic mineral, potash feldspar, crystallized contemporaneously with those of the groundmass, and were, therefore, formed *in situ*, and are not of intratelluric origin.

In the hand specimens, the porphyritic facies of the granite-mass is made up of a coarse-grained, light-gray groundmass of quartz, feldspar and biotite, in which are embedded tabular-shaped feldspar phenocrysts, measuring, in extreme cases, two inches in length. The phenocrysts are prevailingly large in size, varying from 30 to 50 mm. long, and from 10 to 15 mm. broad. They are usually tabular, parallel to the clinopinacoid (010), and are commonly twinned according to the Carlsbad law. The cleavage planes parallel to the base (001) and clinopinacoid (010) are distinctly marked, and show characteristic pearly lustre. In color, the phenocrysts vary from a decided pink to a perfect white, and are usually cloudy and opaque.

A thin section of one of the phenocrysts, examined under the microscope, showed the feldspar to be orthoclase, with cleavage perfect, parallel to the base (001), and somewhat less perfect, parallel to the clinopinacoid (010). An average of the extinction angles, measured on the clinopinacoid with reference to the basal cleavage, gave 10° to 12°. The microscope further revealed abundant inclusions of fairly large crystals of feldspar, twinned, in some cases, according to the albite and the Carlsbad laws; and allotriomorphic grains of quartz and biotite orientated, usually along the clinopinacoidal cleavage-planes. Oftentimes, the enclosed min-

[1] See Plate XVII, Fig. 2.

Fig. 2



PORPHYRITIC GRANITE, GREENE COUNTY, GEORGIA.

Fig. 1. View of a Part of the Doming Mass, Ten Miles South of Greensboro.

Fig. 2. Boulder Outcrops of the Porphyritic Granite, near the Northwestern Border of the Mass Shown in Fig. 1.

erals have no definite orientation, but are formed at various angles to the cleavage direction. The inclusions of biotite in the phenocrysts are nearly always visible to the unaided eye. The ratio of phenocryst to groundmass is quite variable, the two probable extremes furnishing the following estimated ratios :— 1:1 and 2:1, with all gradations between. In the 1:1 estimated ratio, the groundmass is of a dark-gray color consisting of almost equal parts of a dark smoky quartz, white and flesh-colored, opaque feldspar, and black biotite, the grains varying from one or two mm. to 5 or 6, in size. In specimens, whose estimated ratio is 2:1, the groundmass consists very largely of biotite, with small proportions of quartz and feldspar. In this instance, the rock appears to be made up of the large white-opaque phenocrysts, twinned according to the Carlsbad law, and occurring side by side with thin layers of the groundmass between them. They have the same orientation, which is suggestive of a flow structure.

Under the microscope, the rock is made up of a coarse-grained groundmass of quartz, feldspar and biotite, in which are embedded phenocrysts of orthoclase, showing at times considerable perthitic structure. The two potash feldspars, orthoclase and microcline, with considerable plagioclase, the extinction angles of which vary from 5° to 14°, indicating, probably, the presence of both albite and oligoclase, compose the feldspathic constituent of the groundmass. The largest grains of the several feldspars contain abundant enclosed grains of the three component minerals of the rock, sometimes orientated along the cleavage planes, and at other times, not. Twinning, according to the Carlsbad, albite and pericline laws, is common among the feldspars. Microcline and plagioclase are very abundant, the latter being roughly idiomorphic. Micropegmatitic intergrowths of quartz and feldspar frequently occur in the groundmass. Occasional crushed areas of a fine-grained, quartz-and-feldspar mozaic, form a small zone about the contact of some of the larger individuals of these two minerals. The biotite frequently occurs as aggregated, intergrown stringers, or lines, occupying the larger interspaces between the feldspar and quartz grains, as well as being distributed through the groundmass. It is considerably altered to chlorite and some epidote; and, in some cases, it carries inclusions of other minerals. Fracture planes, indicative of mechanical stress, are common to both quartz and feldspar. Magnetite grains and inclusions of apatite and zircon crystals are present in microscopic proportions.

A chemical analysis of this rock in the laboratory of the Survey yielded the writer the following results :—

Silica, SiO_2	69.13
Alumnia, Al_2O_3	17.14
Iron Sesqui-oxide, Fe_2O_3	1.52
Lime, CaO	1.85
Magnesia, MgO	0.79
Soda, Na_2O	4.06
Potash, K_2O	5.49
Ignition	0.52
Total	100.50

A weighed portion of the finely powdered fresh rock, digested for three hours in boiling half-normal hydrochloric acid, gave 10.39 per cent. of soluble matter. The above analysis may be compared with analyses of similar rock from Columbia, Hancock, Fayette and Coweta counties.

In the weathered specimens, the feldspar is rendered very dull and chalky white in appearance; while the biotite is very much broken down by hydration and oxidation of the iron, shown in a marked discoloration of a small area immediately surrounding the biotite folia, by the leached ferruginous constituent. The feldspar phenocrysts are reduced mainly by means of exfoliation, or splitting up into smaller fragments, along the cleavage planes. The rock is, by means of temperature changes, hydration and oxidation, further reduced to a coarse-grained sand, composed of quartz, kaolinized feldspar fragments and inelastic, leached folia of biotite.

An examination of hand specimens of rock collected from an outcrop, occurring two and a half miles northwest from the central porphyritic granite area along the Greensboro-Sparta, or White Plains, wagon-road, reveals a medium-grained, even-granular granite, composed of a somewhat dark, highly vitreous quartz, and white, faintly pinkish opaque feldspar, with some biotite.

A microscopic study of this rock shows it to be a medium coarse-grained biotite granite, composed of quartz, feldspar and some biotite shreds, variously altered to chlorite. The quartz is present mostly as large anhedra and smaller grains, filling the feldspar interspaces. It is very badly fractured, and displays irregular double-refraction. The feldspar constituent consists of orthoclase with microperthitic structure, microcline and plagioclase, the latter, probably the species, albite, mostly. With the exception of the plagioclase, the feldspars occur as irregularly bounded grains, without crystal outline, displaying, in the case of the orthoclase, marked cleavage, with the characteristic complexly twinned structure for the microcline, the most abundant feldspar present in the rock.

Twinning, according to the Carlsbad and albite laws, is also common among the feldspars. The plagioclase is present as more or less well defined lath-shaped crystals. Micropegmatitic intergrowths of quartz and feldspar are very common.

Biotite, the chief accessory mineral, is present in very small amounts. It is green to brown in color, in parallel polarized light, with both curved and straight folia, and is considerably altered to chlorite, which is usually broken down to such an extent, as to stain small areas of the adjacent minerals a rusty color from the liberation of ferric oxide. The biotite is farther advanced in alteration, than any of the other minerals present.

At Veazy's store, five miles south of Greensboro, the rock, in the hand specimen, appears to be made up almost entirely of pink and white-opaque feldspar, and dark, smoky quartz. A few shreds of biotite are to be seen. It differs from the biotite granite described above, which occurs two and a half miles northwest of the porphyritic area, in having very much less biotite present, the feldspars being more decidedly pink in color, and somewhat coarser-grained. The microscopic examination is in full agreement with the megascopic description above, and shows the rock to be composed of the feldspars, orthoclase, microcline and plagioclase, and dark, vitreous quartz, with occasional biotite folia. The feldspar is the most abundant mineral present, and both it and the quartz anhedra show the fractured condition, indicative of strain. Micropegmatitic intergrowths of quartz and feldspar are common. The rock from this locality appears, therefore, from the foregoing description, to be a true binary granite.

A comparative microscopic study of the porphyritic granite and the two specimens of even-grained granite reveals the presence of the same minerals, with the two essential ones, quartz and feldspar, in approximately the same proportions for the three localities; but they differ quite markedly in the amount of the accessory mineral, biotite, present, and also in structure. While no definite information could be obtained from the field relations of these rocks, for reasons stated above, the laboratory study strongly indicates, that they represent facies of the same magma, and that the structural differences are the result of difference of physical conditions, under which the various portions of the magma formed. Similar relations and conditions obtain in several other counties, especially Columbia and Fulton.

Extensive areas of granite occur through the south central portion of Greene county, especially in the region extending from Veazy's store to Siloam and White Plains. The rock outcrops mostly as large boulders over the surface, being somewhat extensively exposed along the public roads between the above places.

OGLETHORPE COUNTY

Oglethorpe is the adjoining county on the southwest to Elbert, and to Madison, on the south. It contains large quantities of a most excellent grade of light-gray and dark-blue biotite granites, which extend in a general northeast-southwest direction through the middle and western half of the county.

THE LEXINGTON BLUE GRANITE AREA

Quarrying has been confined, up to the present time, exclusively to the "blue" granite area, with the quarries grouped about two principal centres, namely Lexington and Hutchins, which are some five miles apart in a nearly east-and-west line. The character of the granites occurring in this county can be brought out best in the detailed descriptions of the individual properties, which follow:—

THE LEXINGTON BLUE GRANITE COMPANY'S QUARRY.—This quarry is located half-a-mile west from the county court-house, at the western limits of the town of Lexington. The granite outcrops as flat surfaces and boulders, over the entire surface of a south sloping hill for some half to three quarters of a mile along the direction of a branch, known as Town creek. The quarry is known at present as the "McWhorter and Smith" quarry; and is owned by Messrs. McWhorter & Smith of Lexington. A side track is operated between the quarry and the town, where a second line, about three miles long, joins the Georgia railroad at Crawford. The property is further located 19 miles southeast from Athens, Georgia. Some half-dozen openings have been made in all, covering nearly the entire length of the exposures at the surface along the slope, in an east-and-west direction. Veins of pure white quartz and feldspar, varying from a fraction to several inches in width, cut the granite-mass in many places.

Notwithstanding the presence of these veins in some portions of the rock, large dimensional stone has been quarried and worked into some of the handsomest monuments, produced by any locality in the entire country. The vein occurrence, in other words, is not of such character as to seriously damage the quarry, which is capable of yielding almost any quantity of stone, of good dimensions. No staining of any kind occurs, except in the very thin surface-weathered zone, confined to the topmost layer; and this is due to partial decomposition of the biotite. The very imposing and handsome monument, recently erected by the State of Georgia in the National Park at Chickamauga, was quarried from the Lexington blue granite.[1]

[1] See Plate XIX.

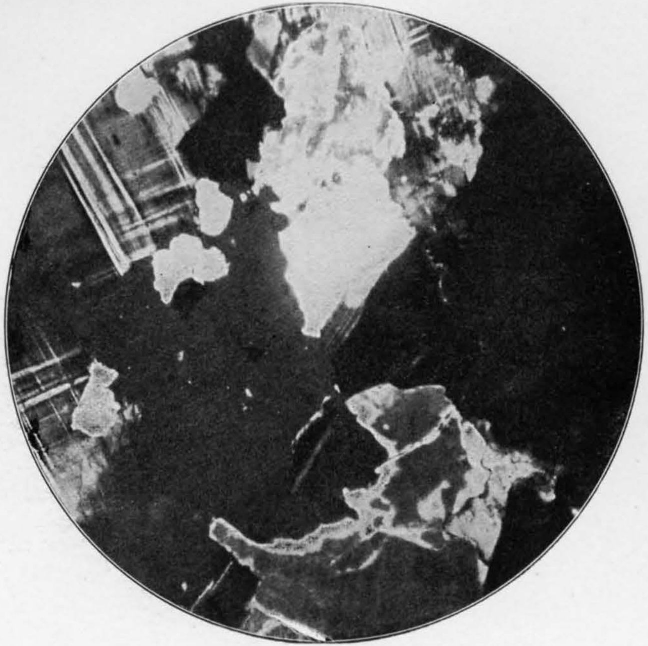


FIG. I. PHOTO-MICROGRAPH OF PORPHYRITIC GRANITE, FROM TEN MILES SOUTH OF GREENSBORO, GREENE COUNTY, GEORGIA.

Crossed Nicols x 74.

FIG. 2. PHOTO-MICROGRAPH OF A PHENOCRYST OF MICROPERTHITIC ORTHOCLASE, SHOWING INCLUSIONS OF QUARTZ, PLAGIOCLASE, BIOTITE, AND VERY SMALL PRISMS OF APATITE, FROM THE GRANITE OF FIG. I.

Crossed Nicols x 74.

Megascopically, the rock is a fine- and even-grained, uniformly massive, dark blue-gray biotite granite, of excellent quality, in which, in addition to quartz, feldspar and biotite, some muscovite is apparent to the unaided eye. The rock is thoroughly suited for all kinds of monumental and ornamental purposes, to which granite is put; it is also an excellent building stone.

Microscopically, the rock is fine and compact in grain, with a hypidiomorphic-granular texture, composed of an admixture of interlocking grains of quartz and feldspar, and biotite altered, more or less, to dark-green chlorite, with some primary muscovite. The feldspar species present, named in order of their abundance, are microperthitic orthoclase, microcline and soda-lime plagioclase. Quartz and feldspar frequently occur as small ovals of micropegmatitic intergrowths, indicating that the quartz crystallized simultaneously with a portion of the feldspar. In addition to these, several other minerals occur in microscopic proportions; but they are not present in sufficient quantity to have any deleterious effect on the stone, when exposed to atmospheric agencies.

Chemical analyses of specimens of the fresh and decayed rock from this locality yielded the writer, in the laboratory of the Survey, the following results: —

	I	II
Silica, SiO_2	70 03	70.50
Alumina, Al_2O_3	15.62	16.84
Iron Sesqui-oxide, Fe_2O_3	1.31	1.53
Lime, CaO	2.45	1.15
Magnesia, MgO	0.52	0.18
Soda, Na_2O	4.82	4.47
Potash, K_2O	5.42	4.52
Ignition	0.77	1.06
Total	100.94	100.25

A comparison of the analysis of the fresh rock in column I, from this quarry, with analyses of similar granite from the Oglesby blue granite area, columns I, II, III and IV, page 223, will at once prove their identity, which is further fully confirmed by the field and microscopic evidence.

Recalculating the analyses in columns I and II of the above rock, and assuming the iron to remain constant, we find by calculation a total percentage loss for the entire rock, in passing from the fresh granite to the stage in decay indicated by the analysis, in column II, equivalent to 14.56 per cent.[1]

Other tests made on specimens of rock from this quarry gave the following figures: —

[1] For a complete discussion of the weathering of this rock, see Chapter V of this report.

Specific gravity at 27°C.	2.666
Weight of one cubic foot of stone expressed in pounds	166.25
Number of cubic feet of stone contained in one ton (2,000 pounds)	12.0
Percentage (ratio) of absorption	0.092

The last figures indicate a very low absorption for the stone; it would not be appreciably affected by frost action.

The rock weathers into a yellowish, iron stained material, through decomposition of the biotite, and the material crumbles freely under pressure. The feldspars become perfectly opaque and lustreless, yielding finally a kaolinized mass.

THE DIAMOND BLUE GRANITE COMPANY'S QUARRY. — This property was controlled by a company from Augusta, Georgia; but it is now owned by Mr. J. W. Lamar of the same city, who bought the property from the above company, of which he was a member. The quarry is located two miles southwest from Hutchins, and six miles southwest from Lexington. A railroad switch is operated between the quarry and Hutchins on the Georgia railroad. The original tract of land embraced some 90 acres in all, on which four openings were made, and rock quarried. The openings are some distance apart. The rock is exposed as flat-surface and boulder outcrops. No work has been done for several years. It is estimated, that from 200 to 300 car-loads of stone were removed. This was used almost exclusively for monuments, and was shipped to a number of places outside of the State. The openings were made on each side of a small stream, tributary to Barrow creek, with the main quarry located on a 20° to 30° slope.

Megascopically, the rock is the same fine- and even-grained dark blue-gray biotite granite, as that worked at Lexington and Oglesby. Some muscovite is apparent in the hand specimen. As in the case of the Lexington and Oglesby rocks, the biotite is remarkably uniformly distributed through this rock, as finely divided plates, and imparts to the stone a striking uniformity in color. A few veins of white feldspar and quartz were observed in the quarry; but they are not so abundant as in the Lexington quarry. The rock in these localities is identical, and would, of course, have the same use and value in the market.

A microscopic study of a thin section of this rock reveals a fine-grained biotite granite, with a hypidiomorphic-granular texture, and composed of quartz, feldspar, biotite and a considerable number of muscovite plates, interlocked in an intricate fashion. The feldspars have a decidedly bluish-gray tone, and consist, according to abundance, of the species, microperthitic orthoclase, microcline and soda-lime plagioclase, twinned according to the several feldspar laws. The single orthoclase individuals display good cleavages. The muscovite nearly equals the biotite in amount. The latter is variously altered to dark-green, opaque chlorite and some epidote. Microscopic accessory minerals are present, but not in quantity and character, sufficient to produce a deleterious effect, on exposure of the stone.

Chemical analyses of specimens of the fresh rock from various openings on this property, made in the Survey laboratory, yielded the writer the following results: —

	I	II
Silica, SiO_2	70.30	69.53
Alumina, Al_2O_3	16.17	16.46
Iron Sesqui-oxide, Fe_2O_3	1.19	1.15
Lime, CaO	2.61	2 10
Magnesia, MgO	0.31	0.85
Soda, Na_2O	4.72	5.00
Potash, K_2O	4.88	4.91
Ignition	0.63	0.91
Total	100.81	100.91

I From specimens of granite from the main quarry.
II From specimens of the granite from the remaining three openings at various points over the property, mixed.

The resistance of this rock to chemical agents is shown in the treatment of a weighed portion of the finely powdered rock in boiling half-normal hydrochloric acid for three hours, yielding 9.77 per cent. of soluble matter. A partial quantitative analysis of the soluble portion gave: —

Iron Sesqui-oxide, Fe_2O_3 } Alumina, Al_2O_3 }	4 23
Lime, CaO	0.54
Magnesia, MgO	trace
Soda, Na_2O	0.64
Potash, K_2O	1.09
Total	6.50
Undetermined	3.27
Total	9 77

The identity of this with the Lexington and Oglesby granite is established, on comparing the two analyses in columns I and II with similar analyses of the fresh rock from the above localities on pages 208 and 212.

Other tests made on specimens of this rock gave the following figures: —

Specific Gravity	2.666
Weight of one cubic foot of stone expressed in pounds	166.62
Number of cubic feet of stone contained in one ton (2,000 pounds)	12.0
Percentage (ratio) of absorption	0.088

It will be observed from these figures, that this rock possesses a very low absorptive power. It will therefore, not suffer appreciably from frost action.

Tests made on specimens of the Diamond Blue Granite Company's granite at the Watertown Arsenal, January 17th, 1894, Major J. W. Reilly, U. S. A., commanding, to determine the compressive crushing strength of the rock, gave the following results: —

Test No.	How Tested	Size	Pressure per Square Inch
7,304	On Bed	3.07″ x 3.06″ x 3.04″	26,340
7,307	On Grain	3.16″ x 2.99″ x 3.10″	23,860

These figures indicate a very superior compressive crushing strength for this granite, being nearly double the strength of the average granite.

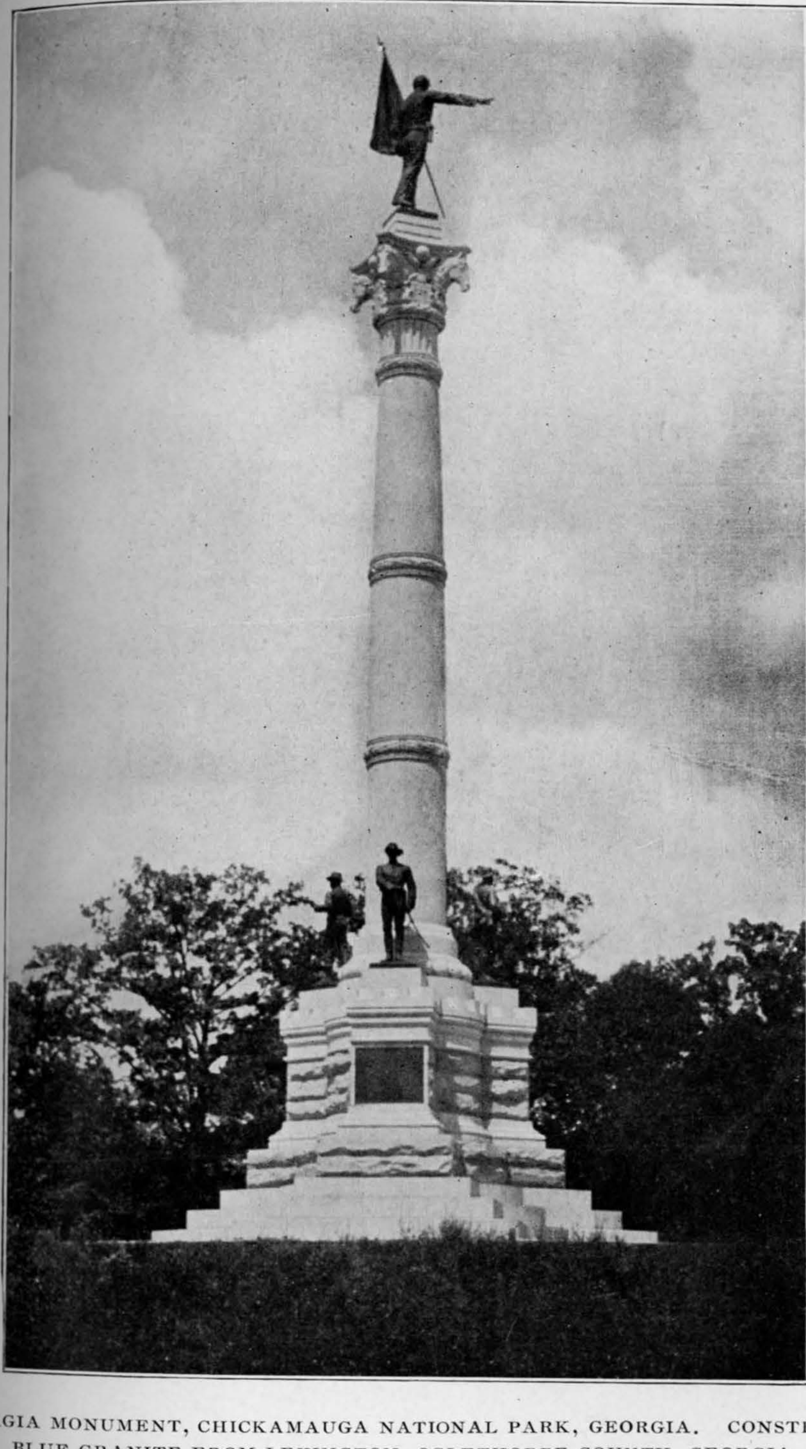
One of the principal openings on this property, from which considerable stone has been quarried, is one and a half miles west from Hutchins on the south side of the wagon-road, leading from Hutchins to Mr. Nat. Arnold's. It is in a boulder outcrop. A thin section under the microscope reveals the same structure and the minerals in the same relative proportions, as that from the main quarry.

Outcrops of the same granite in boulder form occur in numerous places along the public dirt-road leading from the Lexington Blue Granite quarry to the Diamond Blue Granite Company's quarry, a distance of approximately six miles. This well illustrates the continuity of the belt of blue granite in an east and west direction.

THE HEATH QUARRY. — The Heath quarry is located two miles west from Hutchins, on the south side of the wagon-road, and about a mile a little north of west from the main quarry of the Diamond Blue Granite Company. Continuous outcrops of the same granite are seen along the wagon-road between the two quarries. The quarry consists of several openings made near together in flat-surface or sheet outcrops of the rock. A number of small veins of quartz and feldspar cut the granite-mass; but they are not sufficiently numerous to damage the quarry.

Megascopically, the rock is the same uniformly fine-grained, dark-blue biotite granite, as that quarried near Lexington, and by the Diamond Blue Granite Company, in the vicinity of Hutchins.

A microscopic study of a thin section reveals the same fine-grained, somewhat hypidiomorphic-granular rock, as the Diamond Blue Granite Company's granite. It is composed of quartz,



THE GEORGIA MONUMENT, CHICKAMAUGA NATIONAL PARK, GEORGIA. CONSTRUCTED OF BLUE GRANITE FROM LEXINGTON, OGLETHORPE COUNTY, GEORGIA.

feldspar and biotite with considerable muscovite. Named in the order of their abundance, the feldspathic species are orthoclase, microcline and soda-lime plagioclase. The biotite is considerably altered to a dark-colored, opaque chlorite and some epidote. Zircon, apatite, garnet and pyrite are present sparingly as microscopic accessories.

To the south of Heath's quarry, an eighth of a mile, in a strip of woods, are immense boulder outcrops of the same granite, which have been worked to a slight extent.

A microscopic study of this rock reveals the same texture and mineral composition as the one above. Muscovite nearly equals the biotite in amount, and the potash feldspars, orthoclase and microcline, are present, apparently in about equal proportions.

THE N. D. ARNOLD PROPERTY. — On the north side of the wagon-road, a quarter of a mile north from and opposite the Diamond Blue Granite Company's opening, and one and a half miles west of Hutchins, are several openings close together, from which a considerable quantity of stone has been quarried. A few veins cut the rock, but not to any damaging extent. The rock is the same fine-grained, dark blue-gray biotite granite.

Microscopic examination shows the presence of the following minerals in the order of their abundance: Microperthitic orthoclase, microcline, some plagioclase, quartz, biotite and muscovite, with the microscopic accessories, chlorite, epidote, apatite and garnet. The texture is hypidiomorphic-granular, and the essential minerals interlock closely in an intricate manner.

About a half to three-quarters of a mile further north, on the same property, is another exposure, where a recent attempt has been made to get out some rock.

DR. WILLINGHAM'S PROPERTY. — Immediately on the southwest side of the Georgia railroad, one and a half miles northwest from Crawford, are three or four openings in granite boulders, in an open field, owned by Dr. W. M. Willingham, of Crawford. The boulders are almost entirely buried in the residual clay derived from their decay. The stone has not been worked for some time. This is the same fine-grained, dark blue-gray biotite granite, as that described from the above localities.

Under the microscope, the texture is hypidiomorphic-granular, with the anhedra of quartz and feldspar closely dove-tailed into each other; while somewhat idiomorphic plates of biotite and muscovite fill the interspaces. The biotite is partially altered to chlorite, and is intimately associated with much muscovite. Orthoclase and microcline are the predominating feldspars, with the former in somewhat larger quantity than the latter. A few scattered grains of magnetite, in addition to a few other of the commonly occurring accessories, are present.

THE WILKINS PROPERTY. — Only one opening has been made on this property. It is in an immense boulder directly opposite Dr. Willingham's quarry, and on the northeast side of the Georgia railroad, one and a half miles north of Crawford. The Willingham and Wilkins openings are just across the railroad from each other, not more than a quarter of a mile apart. Macroscopic and microscopic study show the rock to be the same dark blue-gray biotite granite, containing the same minerals, in the same relative proportions. The microcline is equal to, if not greater, in abundance, than the orthoclase.

THE JOHNSON PROPERTY. — Two and a quarter miles northwest from Lexington, on the south side of the railroad between Lexington and Crawford, are large boulder outcrops in the open field. One of these has been partially worked up. They are numerous over the greater portion of the field, and continue beyond the two-mile post, in the direction of Lexington. Field and microscopic study show the rock to be the same blue granite, with biotite as its chief accessory, as is described above. Considerable muscovite is present, closely associated with the biotite. Microcline is the most abundant species of feldspar present, with orthoclase next.

Outcrops of the blue granite are traced along the Georgia railroad, from Hutchins to as far south as approximately one mile south of Maxey's station, giving a southward extension to this belt, of from seven to eight miles from Hutchins.

THE LIGHT GRAY GRANITE AREA

So far as the exposures in the field indicate, the light-gray granites are immediately adjacent to and roughly parallel with the blue granite area, which they limit on the southeast. The two areas have the same general northeast-southwest direction through the counties of Oglethorpe and Elbert, with, in many places near Elberton, traceable gradations into each other. The belt of gray granite does not extend as far southwest in Oglethorpe as the blue granites do. It outcrops chiefly at two points: one, in the north central portion of Oglethorpe; the other, on the east side of Elberton in Elbert county. The Oglethorpe outcrops of this rock are detailed in the description of the individual properties below, after which follows a general summary of the two belts in the various counties.

THE O. H. ARNOLD PROPERTY. — Exposures over some five acres or more, as flat surfaces, occur about ten miles northeast from Lexington, in the northern part of Simston district near the Glade district boundary. The main outcrops are found on the Arnold place, which is adjacent to, and once formed a part of, Mrs. Echols' property; with a continuation of the outcrops on the latter's place. The rock is in every way a superior building stone, with an inexhaustible supply indicated. No work has been done, save that a few stones have been obtained at times from the surface raise for chimneys and foundations for dwellings in the immediate neighborhood. Carlton, a small station in Madison county, on the Seaboard Air Line railway, is the nearest railroad point. It is from seven to eight miles distant, in an air line.

In the hand specimen, the rock reveals a medium-grained, light-gray biotite granite, in which the component minerals, quartz, feldspar and biotite, are readily distinguishable.

Microscopically, it is a compact, medium-grained, somewhat hypidiomorphic-granular biotite granite, composed of an admixture of interlocking quartz and feldspar grains, with rather stout shreds and plates of biotite, variously altered to dark-greenish chlorite, and more or less intergrown with foils of muscovite. The feldspars present are orthoclase, intergrown with a second feldspar in microperthitic structure, microcline, and some plagioclase. Epidote, zircon, apatite and a few scattered grains of iron oxide are present in microscopic proportions. The rock is well adapted to the various kinds of general architectural work.

About three quarters of a mile a little west of north from Tiller's store, immediately in the Echols Mill road, is a flat-surface outcrop of the same rock, of about one acre in extent.

THE ECHOLS MILL PROPERTY. — About eleven miles northeast from Lexington, in the southern part, and near the boundary, of Glade district, are very extensive flat-surface and boulder outcrops of the light-gray granite. At the very lowest estimate, there are some 30 or more acres of the exposed rock around the mill, with more or less continuous outcrops for several miles, in a southeast-northwest direction. An abundant water-power is immediately at hand; as Millstone creek, a good sized stream, which furnishes power for operating the mill, flows directly across the main exposed mass of the rock. The rock has a slope along the stream, at this point, of from 10° to 15°. The location is a most favorable one, for easy and ready working, on account of the quality and quantity of the rock, and because of other conditions present. No work has been done, save to the extent of getting out some rock for chimneys, foundations, dams etc., to meet the demands of the immediate neighborhood. Outcrops of the rock are to be traced for a distance of some two miles along the road leading from Tiller's store to the mill. Outcrops of this granite extend as far north and northwest as within close proximity to Point Peter P. O., in Glade district, a distance of some two or three miles.

Beyond O. H. Arnold's and Mrs. Echols in Simston district, and near the boundaries of Simston, Glade and Goose Pond districts, at Robert Harris's, are numerous outcrops of the same rock, 12 1-2 to 13 miles northeast from Lexington.

Echols mill is six miles in an air-line from Carlton, the nearest point on the Seaboard Air Line railway.

The rock is a medium-grained, light-gray biotite granite, and is in every respect identical with the Swift and Wilcox, and Tate and Oliver granite quarried near Elberton. In addition to the quartz, feldspar and biotite, some folia of muscovite are apparent in the hand specimen. The rock is an excellent one, and is thoroughly adapted to all grades of general architectural work, to which granite of this color can be put. It is entirely free from all blemishes and imperfections.

A thin section of the rock, under the microscope, reveals a compact and medium-grained granite, with a hypidiomorphic-granular texture. It is composed of an aggregate of intricately interlocking quartz and feldspar, and biotite with a few shreds of muscovite The feldspar consists of the varieties, microperthitic orthoclase, microcline and some plagioclase. Chlorite, as as an alteration product of biotite, some inclusions of zircon and apatite, and a sparse scattering of magnetite grains make up the microscopic accessory minerals present.

A chemical analysis of specimens of the rock from Echols mill, in the laboratory of the Survey, yielded the writer the following results: —

Silica, SiO_2	68.79
Alumina, Al_2O_3	16.48
Iron Sesqui-oxide, Fe_2O_3	0.98
Lime, CaO	1.76
Magnesia, MgO	1.30
Soda, Na_2O	4.74
Potash, K_2O	5.85
Ignition	0.38
Total	100.28

A comparison of this analysis with the analyses of the Swift and Wilcox, and the Tate and Oliver granite in Elbert county reveals the essential identity of the granite from these localities. Attention is called to the low percentage of the iron and the correspondingly high percentage of the magnesia content, in the above analysis.

Digestion of a weighed portion of the finely powdered rock in boiling half-normal hydrochloric acid for three hours, yielded 8.37 per cent. of soluble matter. A partial quantitative analysis of the soluble portions gave the following figures : —

Alumina, Al_2O_3 / Iron Sesqui-oxide, Fe_2O_3	2.75
Lime, CaO	0.93
Magnesia, MgO	trace
Soda, Na_2O	0.30
Potash, K_2O	0.99
Undetermined	3.40
Total	8.37

The rock weathers in a manner similar to that from the Elberton light gray granite area.

Other tests made on this rock gave : —

Specific Gravity at 27° C.	2.657
Weight of one cubic foot of stone expressed in pounds	166.06
Number of cubic feet of stone contained in one ton (2,000 pounds)	12.0

Immediately in front of Brown's church, two and a quarter miles northeast from Lexington, is an outcrop of an immense boulder of a light-gray and fairly coarse-grained biotite granite. The exposed portion of the rock was badly discolored from weathering, the surfaces consisting of a decidedly yellowish brown in color.

THE ANDREW QUARRY. — This quarry, which is owned by Mr. J. J. Andrew, of Carlton, is located two miles southeast from Carlton, near the county-line, and within 25 paces of Broad river. Some rock was quarried from a boulder outcrop seven years ago, for bridge piers. The outcrop is not very extensive, and the amount of stone quarried is comparatively small.

In the hand specimen, this is the same granite as that, described above, from Echols mill in Oglethorpe county, and around Elberton in Elbert county. In color, grain and texture, specimens of the granite from the above localities can not be distinguished.

This rock is especially desirable as a general building stone. It is a fine-grained biotite granite, light gray in color.

GNEISS

About three and a half to four miles northeast from Lexington, near Patman's old mill-site, are extensive ledge and boulder exposures of granite-gneiss. The outcrops occur along the public wagon-road and the stream, on which the mill is located. The rock varies quite markedly in structure, grain and color. In texture, it varies from coarse- to fine-grained; in structure, from schistose to massive; and in color, from a dark medium-gray to very light. The difference in the color of the rock is due to the variation in abundance and distribution of the biotite in the rock, the mica being quite uniformly distributed in some portions and almost absent from others. The outcrops are quite continuous along the public dirt-road from this point into Lexington. This rock is well suited for rough masonry and general road purposes.

Résumé

The granites of Oglethorpe county are quite as variable in structure, color and grain; and are as abundant and of as good quality as those described as occurring in Elbert county. The two belts of dark blue-gray and light-gray, fine- and medium-grained granites, respectively, are continuous through the two counties in a northeast-southwest direction, and present scarcely any variations in color, grain or texture at any point along their extent.

On the contrary, uniformity in color, grain and texture are particularly characteristic of the masses throughout their limits. The blue granite is strictly a monumental stone of the best quality; while the lighter gray rock is an equally superior granite for general building purposes. The two belts are contiguous and roughly parallel, without any directly traceable gradation into each other, except in the Elberton region, where it becomes somewhat apparent. The light-gray rock is coarser in grain than the blue granite; and the biotite is distributed as larger and stouter plates, through the rock, although the biotite content is quantitatively the same for the two areas. The feldspar constituent also presents a marked blue-gray tone in the blue granite, while it is decidedly white in the light-colored stone.

As is seen to be the case in Elbert county, the Oglethorpe correlatives of these areas carry quartz, the several feldspar varieties, microperthitic orthoclase, microcline and some soda-lime plagioclase, and biotite, as the component minerals, with more or less muscovite, closely intergrown with the biotite. The microscopic accessory minerals are the same in each case.

Their chemical constitution remains practically constant. For sake of comparison, a list of chemical analyses of the Oglethorpe fresh granites is here given. They may be readily compared with similar ones from Elbert county on page 223.

	I	II	III	IV
Silica, SiO_2	70.30	69.53	70.03	68.79
Alumina, Al_2O_3	16.17	16.46	15.62	16.48
Iron Sesqui-oxide, Fe_2O_3	1.19	1.15	1.31	0.98
Lime, CaO	2.61	2.10	2.45	1.76
Magnesia, MgO	0.31	0.85	0.52	1.30
Soda, Na_2O	4.72	5.00	4.82	4.74
Potash, K_2O	4.88	4.91	5.42	5.85
Ignition	0.63	0.91	0.77	0.38
Total	100.81	100.91	100.94	100.28
Specific Gravity	2.666	2.666	2.657	

Columns I, II and III are analyses of the blue granite.
Column IV is an analysis of the light-gray granite.

Percentage (ratio) of absorption . . 0.092 (Lexington Blue Granite Quarry)
" " " . . 0.088 (Diamond Blue Granite Quarry)

Compare these figures with the results from similar tests on the Oglesby blue granite, Elbert county, page 223, and it will be seen that the two stones are the same.

The enclosing or country rock in the two counties consists of highly contorted and crumpled granite-gneisses and mica-schists, through and into which the granites have been intruded. They are, therefore, relatively older in age than the latter rocks.

MADISON COUNTY

Madison lies immediately west of Elbert county, and is separated from it by the Broad river, the boundary line between the two counties. The granites are confined to the extreme southeastern portion of the county, forming a part of the Elbert-Oglethorpe area.

THE BROWN AND DEADWYLER PROPERTIES.—The quarry on this property is two and a half miles a little east of south from Carlton; half-a-mile west from the junction of the North and South forks of Broad river; and one mile south from the Coggins Granite Company's Hill quarry. The opening lies wholly on Mr. Brown's property, within half-a-dozen feet of the line between Mr. Brown's and Mrs. Deadwyler's properties, and is located on a ridge, in large boulder outcrops. The rock continues to outcrop, as boulders, on Mrs. Deadwyler's place, for at least from 300 to 400 yards in a northeast direction. It is a continuation of the Oglesby blue granite across the river into Madison county. The opening was made about six years ago, and the rock was used for bridge-piers along the Seaboard Air Line railway.

Megascopically, it is the same massive, uniformly fine-grained, dark-blue granite, as that worked around Oglesby, and carries, to some extent, the same biotite specks, averaging a millimeter or more in diameter, as in the case of the Deadwyler quarry, near Oglesby. It is as free from imperfections, and equally as well adapted to the various grades of work, as the above rock.

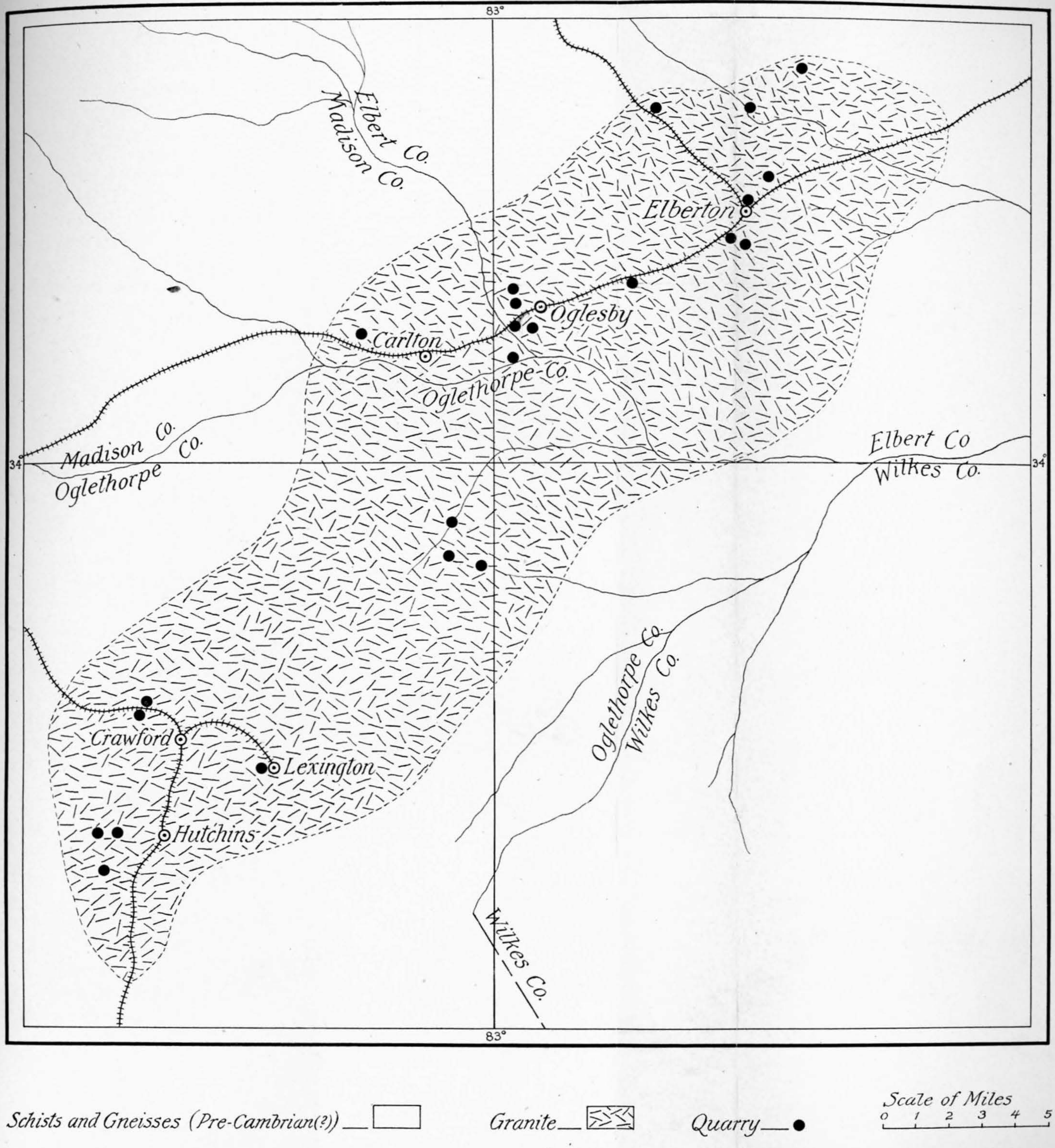
Microscopically, it is a compact, fine-grained, even textured biotite granite, composed of bluish-gray feldspar, with somewhat pearly cleavage faces, clear colorless quartz, and the ferro-magnesian mineral, biotite, and its alteration product, chlorite. The constituent grains of these minerals are closely and intricately interlocked. The feldspathic species are microcline, microperthitic orthoclase, and some plagioclase, the orthoclase and microcline predominating, being present in about equal amounts. Some muscovite, occasional grains of magnetite and epidote, and inclusions of zircon and apatite occur in microscopic proportions.

A chemical analysis made in the Survey laboratory, from specimens of the rock from this locality, yielded the writer the following results : —

Silica, SiO_2	70 18
Alumina, Al_2O_3	17.30
Iron Sesqui-oxide, Fe_2O_3	1.20
Lime, CaO	2.03
Magnesia, MgO	0.64
Soda, Na_2O	4.36
Potash, K_2O	4.77
Ignition	0.35
Total	100.83

The chemical analysis, in addition to the field and microscopic study, further identifies this as the same as the Oglesby granite. Compare the above analysis with those in columns I, II, III and IV on page 223.

THE DAVID PROPERTY. — Two miles west of Carlton, on the north side of, and less than a quarter of a mile from, the Seaboard Air Line railway, is an outcrop of very fine-grained, light blue-gray biotite granite. The opening is located in a body of pine woods on the side of a deep ravine. To the southwest of this outcrop, about fifty paces, is a large area of coarse-grained, contorted biotite granite-gneiss, exposed in the Seaboard Air Line railway cut, at the overhead bridge. The relations, so far as were determinable in the field, warrant the statement, that the granite has been intruded into the gneiss, and is therefore younger in age. With the exception of its being very much finer in grain and texture, it is, from all appearances and study, similar to the Brown and Deadwyler blue granite ; and it may represent a dike intru-



MAP OF THE OGLETHORPE-MADISON-ELBERT GRANITE AREA.

sion into the gneiss, formed at the same time and from the same magma as that granite. The exposures of the David granite were not sufficient, to determine the limits or boundaries of the mass. Only a small opening has been made. From this, a few pieces were quarried some years ago for bridge piers. In the hand specimen, some muscovite shreds, in addition to the quartz, feldspar and biotite, are readily discernible by the unaided eye.

Microscopically, the rock is very fine-grained; and, as regards its mineral constituents and their distribution, it is identical with the Oglesby blue granite. The microcline is somewhat less abundant than has hitherto been observed; while the orthoclase is the most abundantly occurring feldspar.

THE MARY RUSSELL SISTERS PROPERTY. — One mile south of Carlton, in the Fork district, immediately on the north bank of Broad river, are large boulder outcrops of a light blue-gray, medium-grained biotite granite. Also, a less extensive exposure of the same rock is to be seen a few hundred yards further north, in the edge of a body of pine woods. A comparison of this with the Brown and Deadwyler granite shows very striking similarity in texture and grain, the latter rock being probably a shade darker in color. They are evidently portions of the same granite mass, with the slight variation in color noted. The exposure on the river has been slightly opened. More or less muscovite, in addition to the essential minerals, quartz, feldspar and biotite, is seen distributed through the hand specimen.

Microscopic study of a thin section of this rock reveals about equal proportions of the two micas, muscovite and biotite. It is therefore classified as a muscovite-biotite granite. It is a compact, medium-grained rock, with hypidiomorphic-granular texture, in which orthoclase greatly predominates over the other feldspars present. The microcline is at the minimum in this rock, when compared with its occurrence in the other similar granites of this area.

This property is owned by Miss Mary Russell and her sisters of Carlton.

THE EBERHART PROPERTY. — One mile east of Carlton, in the Fork district, on the property of Mr. J. B. Eberhart, of Carlton, are large boulder outcrops exposed on a wooded hill slope, on the south side of the Seaboard Air Line railway, and on the north side of the public wagon-road leading from Carlton. Only one of the boulders has been opened. The hand specimen indicates a granite very similar in grain and texture to that found on the Russell Sisters' place. The Eberhart rock differs, however, from the latter, in having a very slightly gneissoid appearance and a decidedly pinkish hue for the feldspars, imparting a moderately light pinkish-gray color to the stone. It is quite probable, that the pinkish cast of the feldspar individuals indicates, as elsewhere suggested in this report, an incipient stage in weathering. Some light-colored mica, probably muscovite, is seen in the hand specimen, in addition to the dark-colored biotite.

The microscope indicates nearly equal proportions of muscovite and biotite, with the latter predominating to a slight extent, perhaps. It is therefore a muscovite-biotite granite. The rock consists of quartz, feldspar and mica (biotite and muscovite). As in the case of the rock from the Russell place, orthoclase in the Eberhart granite is present in excess over microcline and plagioclase, with the microcline likewise at a minimum, and with a somewhat larger amount of plagioclase. A study of the two rocks strongly indicates that they are the same. The biotite is considerably altered to chlorite and some epidote, and indicates some leaching.

The rock weathers to a dirty, yellowish-brown color, due to oxidation and hydration, with consequent leaching, of the biotite; and, while held together, it very readily crumbles, under slight pressure, into a similarly colored granitic sand.

Boulder outcrops of the same rock occur in a field, on the south or opposite side of the wagon-road, from that in the woods.

ELBERT COUNTY

The granites of Elbert county, as seen from the map opposite page 200, are confined chiefly to the middle southwestern part of the county, with more or less extensive outcrops occurring in the adjacent portions of Madison and Oglethorpe counties. Numerous quarries, yielding superior monumental and building stone, well suited for the various grades of general architectural work, have been operated somewhat continuously for a number of years, in the vicinity of Oglesby and Elberton, on the main line of the Seaboard Air Line railway. The individual properties can, therefore, for convenience be best grouped and described under the following two headings: (a) The Elberton area, and (b) The Oglesby area.

THE ELBERTON AREA

THE HEARD PROPERTY.—The three openings on this property, from which stone has been obtained, are located just outside of the city-limits of Elberton, about one mile southwest from the court-house, and within close proximity to each other. The openings are of small dimensions, and only a very limited amount of stone has been quarried. The most recent of the three was opened about three and a half years ago, for the stone used as trimmings in the new city hall in Elberton. An examination of the openings revealed a very homogeneous rock, cut by several veins of intergrown quartz and feldspar, an inch or more in width; also, occasional small segregated areas of biotite. Neither the segregations of biotite nor the veins are numerous enough to in anywise prevent stone of good dimensions being quarried.

Macroscopically, the rock is a massive, medium-grained, light-gray biotite granite, in which biotite, quartz and feldspar are readily recognized by the unaided eye. In places, the rock has assumed somewhat of a gneissoid structure, resulting from pressure metamorphism.

Microscopically, (Museum No. 1,723), it is a medium-grained rock, composed of an aggregate of interlocking anhedra of quartz and feldspar, with considerable filaments of a somewhat idiomorphic biotite, more or less altered to a deep-green and greenish-black chlorite. The feldspar constituent consists of the potash species, orthoclase and microcline with microperthitic structure, and some plagioclase. The orthoclase and microcline are present in about equal proportions. Some primary shreds of muscovite are intergrown with the biotite. Microscopic accessory minerals are present, both as primary and secondary products; but they are of such character, and occur in quantities so small, as to in no-wise detract from the durability and other desirable qualities of the rock.

Weathering.—The rock is weathered to a slight depth. The prevailing color of the weathered surface is a dirty yellow, rusty color. In the firm, but decayed, rust-colored rock, the essential minerals are still discernible by the unaided eye. As shown under the microscope, the weathering begins with a dullness and irregular opacity of the feldspars, and a corresponding leaching of the biotite, the iron of which is oxidized and liberated as a yellowish staining. A more advanced stage indicates a more general and complete break-down of the mica than of the feldspars.

The rock is the same as that quarried by Messrs. Swift and Wilcox, one mile south of Elberton, with the exception of its containing a slightly greater amount of biotite and being a shade finer in texture. This property is owned by Mr. L. M. Heard, of Elberton.

BRUCE'S MILL. — Outcrops of the same rock, as that described above, occur over the hillside at the mill, belonging to Mr. McAlpin Arnold, of Elberton, along the mill-stream, and in the adjacent ravines, in the form of ledges. Also, as flat surfaces and boulders, for some distance along the mill-road, leading from town, and in the southwest field. These exposures are just outside of the city limits, to the southwest. Considerable variation with respect to texture and color, the latter, due to variability in quantity of the biotite, is observed in places. The color, however, is prevailingly light-gray; and the rock is medium-grained in texture. The stone of this locality has never been worked.

Various other outcrops of the same rock are observed on the same side of the city, near the Heard and the Mill properties; but none has been opened.

THE SWIFT AND WILCOX PROPERTY. — This property includes 160 acres, over which extensive outcrops of granite, in the form of boulders and flat surfaces, exist. A quarry was opened in 1888 or 1889, for the purpose of getting out stone for bridge-piers, along the line of the Southern railway. It was worked again in 1890, when rock was quarried for a similar purpose along the Seaboard Air Line railway. The last systematic work was done in 1893.

The quarry is located one mile south of Elberton, on a south sloping hillside, in a granitic outcrop of several acres' extent. Two openings have been made within a few yards of each other; and a considerable quantity of stone has been quarried. The rock in the main opening, nearest the top of the hill, is capped on its upper side with some three to six feet of fine, yellow, siliceous soil, somewhat loamy in character, derived from the weathering of the granite. The gradation from soil into firm and moderately fresh rock is sharp and abrupt. The rock immediately in contact with the soil is hard and firm; but it is slightly discolored by a partial breaking down of the mineral constituents. Small granite boulders, which crumble with ease, under pressure of the hand, into a coarse granitic sand, are distributed through the loose mantle.

The rock is a perfectly massive, homogeneous granite, of pleasing tone, and admirably suited to all grades of general architectural work. It can be readily and easily worked, and will, to all appearances, admit of fine hammered work. It is susceptible of good polish. Field examination revealed no blemishes nor imperfections, save occasional segregations and veins, which can readily be avoided in working, without waste.

Macroscopically the rock is a homogeneous, massive and medium-grained, light-gray, biotite granite, in which feldspar, quartz and biotite are easily recognizable with the unaided eye.

Microscopically (Museum No. 1,772), it is a medium-grained and uniformly even-granular rock, consisting of an admixture of interlocking grains of quartz and feldspar, with somewhat large, stout plates and shreds of biotite, intergrown with occasional foils of muscovite. The biotite is, to a considerable degree, altered to a dark, greenish, nearly opaque chlorite. The feldspars present in the order of their abundance, are orthoclase in microperthitic intergrowth with a second feldspar; microcline; and some scattered laths of plagioclase. These occur usually well twinned after the Carlsbad, albite and pericline laws; and, in case of the larger single orthoclase crystals, they show good cleavage. Intergrowths of feldspar and quartz, as micropegmatitic structure, are very common. Other microscopic accessory minerals, apatite and zircon chiefly, are sparingly present.

Analyses of the fresh and decayed rock have been made by the writer in the chemical laboratory of the Survey, with the following results: —

	I	II	III
Silica, SiO_2	69.45	69.00	73.90
Alumina, Al_2O_3	15.93	17.31	13.78
Iron Sesqui-oxide, Fe_2O_3	1.31	1.31	1.23
Lime, CaO	1.91	1.18	0.53
Magnesia, MgO	0.55	0.42	0.05
Soda, Na_2O	4.33	4.00	2.92
Potash, K_2O	5.16	4.74	5.43
Ignition	0.50	1.79	2.60
Total	99.14	99.75	100.44

I Analysis of the fresh granite.
II Analysis of the partially decayed granite.
III Analysis of granite soil, two feet below the surface.

The analysis of the fresh rock indicates a granite possessing great durability and power of resistance toward atmospheric agencies. The percentage of silica and lime is normal; while that of the alkalies is moderately high. The iron and magnesium content is accordingly very low. The chemical analysis confirms the microscopic examination.

Other tests on specimens from this quarry show the rock to be all that could be desired, from a standpoint of durability. The ratio, or percentage, of absorption is low, indicating, that the stone can well withstand the deteriorating effect of frost action. The figures are as follows:—

Specific Gravity	2.652
Weight of one cubic foot of stone expressed in pounds	165.75
Number of cubic feet of stone in one ton (2,000 pounds)	12.0
Percentage (ratio) of absorption	0.090

Outcrops of the same rock occur at the foot of the slope immediately below the second opening, in the bed of a small stream; and also across the stream on the opposite side from the quarry.

A quarter of a mile south from the main opening (or quarry), and one and a quarter miles S. 20° E. from Elberton, on the same property, are extensive areas of flat-surface exposures of the same granite in an open field. Microscopic study of a thin section from a specimen collected from this locality indicates the presence of the same minerals in the same relative proportions. The rock at this point has the same color and texture as that from the quarry. It is remarkably uniform, and in every respect an excellent stone for the various grades of work. It can be easily worked, and is within a short distance of the Seaboard Air Line railway. Tests made on specimens of rock collected from this locality gave the following results:—

Specific Gravity at 19° C.	2.645
Weight of one cubic foot of stone expressed in pounds	165.31
Number of cubic feet of stone contained in one ton (2,000 pounds)	12.0
Percentage (ratio) of absorption	0.092

Weathering.— The weathering of this rock is in every respect similar to that described under the Heard property, page 203. A thin section of a piece of the sap (partially decayed granite) was examined under the microscope, which indicated that in a majority of the potash feldspar individuals showing cleavage, weathering had progressed in large measure along the cleavage lines, manifested in a darkened effect and what appeared to be slight openings along these planes. Leaching of the biotite and a corresponding yellowish staining, over most of the slide, of iron oxide derived from the hydration and oxidation of the iron in the mica, indicated the partial decay of this mineral. As indicated in the analyses of the fresh and partially decayed rock, columns I and II, page 205, there has been a total loss of only 7.92 per cent. for the entire rock, in passing from the fresh to the partially decayed material.[1] This means, that the process is mainly one of disinte-

[1] See full discussion of this in Chapter IV.

gration (mechanical), rather than of decomposition (chemical); that is, the fresh rock is reduced to a rusty or light-yellow granitic sand, largely through the action of mechanical forces, aided, in some degree, by chemical action.

The following will give some idea of the relative stability of this rock under the influence of chemical agents. Half-a-gramme of the fresh rock was finely pulverized and treated in a covered dish with 100 cc. of boiling half-normal solution of hydrochloric acid, for three hours. By this action 9.20 per cent. of soluble matter was obtained, a partial quantitative analysis of which yielded the following: —

Alumina, Al_2O_3 / Iron Sesqui-oxide, Fe_2O_3	3.69
Lime, CaO	0.26
Soda, Na_2O	0.29
Potash, K_2O	1.02
Total	5.26

This property is owned by Messrs. T. M. Swift and W. M. Wilcox, of Elberton.[1]

THE FAMBROUGH PROPERTY. — This property, which is owned by Mr. L. C. Fambrough, of Elberton, is located about one and three-quarter miles slightly east of south from Elberton, and from a half to three quarters of a mile southwest of the Swift and Wilcox quarry. The rock outcrops as large boulders over some 15 to 20 acres of a steeply sloping, partly wooded hillside, overlooking a small stream. Quarrying, which was first begun in November, 1897, has been confined to a number of the largest boulders. The stone was used for building purposes.

The rock is a light-gray, medium-grained biotite granite, in which quartz, feldspar and biotite are readily distinguished. Microscopic study and field observations mark this as a continuation of the same rock as that on the 160-acre tract, described above, with the possibility of its being a shade finer-grained in texture. The feldspars have a slightly pinkish hue in the hand specimen, due, probably, to incipient alteration. Under the microscope, the rock shows an admixture of interlocking quartz and feldspar grains with biotite foils and shreds. Orthoclase, showing some microperthitic structure, is the most abundant species of feldspar present. It is associated with the other commonly occurring feldspars, microcline and plagioclase, which are present in their

[1] Since this report went to press, Messrs. Swift and Wilcox have divided the property, so that the 80-acre tract, containing the quarry, is now owned by Mr. Wilcox, and that, containing the flat surface outcrops, described on page 206, is owned by Mr. Swift. There is apparently little, if any difference, in the value of the two properties.—W. S. Y.

usual proportions. The ordinary sprinkling of the other microscopic mineral accessories was observed.

The weathering is quite similar to that described above. In the field, the quarried boulders show a rather unusual depth in weathering. The color of the weathered surface is a pinkish red to a yellow, rusty brown.

THE HERNDON AND SWIFT PROPERTY. — This property, owned by Messrs. J. E. Herndon and T. M. Swift, of Elberton, is located two and a half miles south of Elberton on the Jones' Ferry wagon-road, and within a short distance of Mr. Herndon's dwelling-house. The rock outcrops at this point as flat surfaces over several acres, cut by a number of veins, of slight width. So far as could be determined, the rock is a light-gray biotite granite. No opening has been made.

About a quarter of a mile slightly south of east from this exposure, in the Herndon pasture, are boulder outcrops of granite, extending over some thirty to forty acres, through which a moderate sized stream flows. A specimen of the rock collected from one of the boulders at this point in a somewhat advanced stage of decay and badly discolored, revealed a medium-grained biotite granite, which is presumably light-gray in color, when fresh and unweathered. It marks the further extension of the light-gray granites described above.

THE TATE AND OLIVER PROPERTY. — This property is owned by Messrs. E. B. Tate and A. S. Oliver, of Elberton. It is situated on the northeast side of, and about one hundred yards from, the track of the Seaboard Air Line railway, in Pine-town, a suburb of Elberton, and approximately half-a-mile northeast from the court-house. A flat-surface outcrop, of less than two acres, is exposed, with the greater part stripped to a slight depth. Southeast, about 100 yards, is a slight ledge outcrop of the same rock, from which a few slabs have been quarried. The space between the two outcrops is covered to a moderate depth with soil.

The rock is a perfectly massive, medium-grained, light-gray biotite granite, in which the black, lustrous shreds of biotite and the fresh, lively appearing feldspar and quartz, are readily distinguished. It is firm and compact in grain, and affords every indication of working well under the hammer, as well as of taking a good polish.

Microscopically, the rock is compact and medium-grained, possessing a partial hypidiomorphic-granular texture. It is composed of an admixture of quartz, feldspar and biotite, with a few scattered intergrown foils of muscovite. The feldspars present, named in

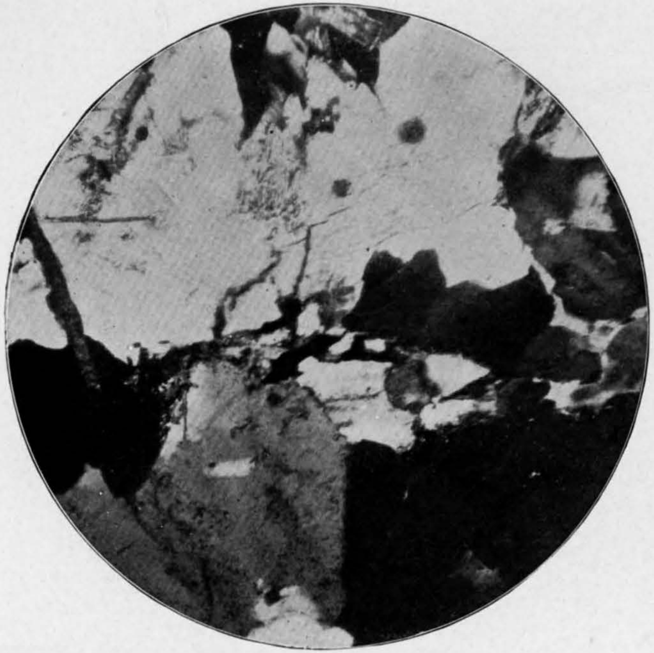


FIG. I. PHOTO-MICROGRAPH OF LIGHT-GRAY GRANITE, FROM ECHOLS' MILL, OGLETHORPE COUNTY, GEORGIA.
Crossed Nicols x 74.

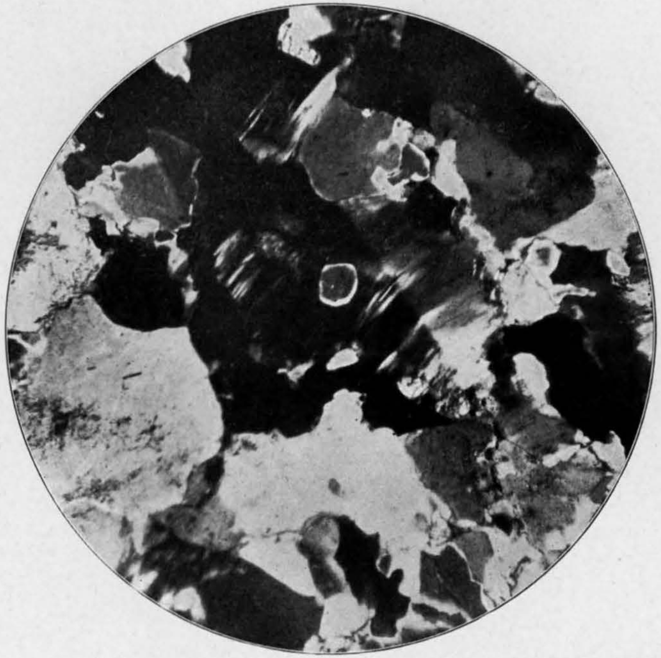


FIG. 2. PHOTO-MICROCRAPH OF THE DARK-BLUE GRANITE, FROM THE CHILDS QUARRY, NEAR OGLESBY, ELBERT COUNTY, GEORGIA.
Crossed Nicols x 74.

order of their abundance, are: microcline, microperthitic orthoclase, and a few laths of plagioclase. Twinning of the feldspar species, according to the Carlsbad, albite and pericline laws, is common. The orthoclase shows good cleavage, in most cases. Micropegmatitic intergrowths of feldspar and quartz, and a few microscopic crystals of apatite and zircon were observed. The biotite is more or less altered to chlorite and epidote. Named in order, the three most abundant minerals in the rock are feldspar, including all the species present, quartz and biotite.

An analysis of this rock, made in the Survey laboratory, yielded the writer the following results:—

Silica, SiO_2	69.25
Alumina, Al_2O_3	16.04
Iron Sesqui-oxide, Fe_2O_3	1.72
Lime, CaO	1.89
Magnesia, MgO	0.31
Soda, Na_2O	4.52
Potash, K_2O	4.94
Ignition	0.43
Total	99.10

It will be observed from a comparison of the above analysis with that of the fresh rock from the Swift and Wilcox quarry, that the two are essentially identical, there being scarcely more than an appreciable variation in the percentages of any one of the constituents. It is clear, therefore, that, from a chemical and microscopical study of the two rocks, they are the same. This is also further confirmed by field evidence.

Absorption test, made on a specimen of the rock from this locality, gave the following result:—

Percentage (ratio) of absorption	0.093

Other tests made yielded the following figures:—

Specific gravity at 19° C.	2.670
Weight of one cubic foot of stone expressed in pounds	166.87
Number of cubic feet of stone contained in one ton (2,000 pounds)	11.9

THE FORTSON PROPERTY.—Eight acres of land were leased for 12 years from Mr. A. C. Fortson in 1893 by Messrs. Swift and Etheridge, of Elberton, which was located N. 25° E. of, and a quarter of a mile from, Goss station on the Toccoa and Elberton branch of the Southern railway. Granite outcrops in the form of boulders, one of which has been worked to a depth of 15 feet, or more, yielding a good quality of stone. No free oxides or sulphides of iron were observed in a field examination of the rock; in fact, no imperfections of any nature were noted. The rock appears well adapted to the various grades of work, for which granite is used.

Megascopically, it is massive and of medium-grain — somewhat darker in color and slightly finer in texture than the Swift and Wilcox granite. The darker color is apparently due to an increase in quartz, which is of a dark and slightly bluish tint, quite uniformly distributed through the rock, with a corresponding increase in the biotite (black mica). Quartz, feldspar and biotite are readily visible to the naked eye.

Microscopically, the rock is a compact, medium-grained biotite granite, composed of an aggregate of intricately interknit anhedra of quartz and feldspar, with a good quantity of regularly distributed plates of biotite, more or less altered to a dark, greenish chlorite and some epidote, with a fair sprinkling of irregular shreds of primary muscovite. The feldspar constituent consists of the species, microperthitic orthoclase, microcline, and somewhat idiomorphic, twinned lamellæ of plagioclase, the orthoclase predominating. The feldspars display characteristic twinning after the several laws; and as a rule, the potash species show good cleavage. The usual microscopic accessories are present, to a limited degree.

An analysis of this rock, in the Survey laboratory, yielded the writer the following results : —

Silica, SiO_2	71.00
Alumina, Al_2O_3	16.33
Iron Sesqui-oxide, Fe_2O_3	1.12
Lime, CaO	1.83
Magnesia, MgO	0.35
Soda, Na_2O	4.80
Potash, K_2O	4.65
Ignition	0.87
Total	100.95

The analysis, when compared with that on page 205, indicates a larger amount of silica, with a proportionally smaller amount of iron oxide ; while the other constituents are essentially the same, as to quantity.

THE BREWER PROPERTY. — Three and a quarter miles north from Elberton, on the north side of Beaver Dam creek, and the west side of the public wagon-road, are outcrops of a biotite granite, at the base of a low and gently sloping hill, on the property of Mr. S. S. Brewer, of Elberton. The rock is a compact, close-grained, light-blue granite, cut in places by a few small pegmatite veins. It is somewhat finer grained and darker in color than the rock previously described; still the component minerals, quartz, feldspar and biotite, are readily detected by the eye.

A microscopic examination of a thin section reveals an admixture of quartz and feldspar with biotite, somewhat altered to chlorite and epidote, and intergrown with scattered foils of muscovite.

Boulder outcrops of the same rock occur at several places between this exposure and the Adams quarry, about one and a half miles east. Outcrops occur again on the two sides of Beaver Dam creek at the east bridge, from one and a half to two miles from the Brewer bridge over the same stream, where rock was obtained for building the former bridge. The most extensive outcrops are observed along the wagon-road on the south side of the stream.

The Brewer rock, in the hand specimen, resembles very closely the Fortson rock at Goss station, described on pages 209 and 210.

THE ADAMS PROPERTY.—The Adams quarry is located in the rear of the dwelling-house of its owner, Mr. R. E. Adams, four and a half miles N. 20° E. from Elberton, which is his post-office. The rock outcrops as large boulders over approximately five acres of ground, extending from the quarry to a branch beyond the Adams residence. Several boulders were opened in 1885 and 1886, for the purpose of getting chimney- and foundation-stone. It was worked on a more extensive scale in 1890, when Messrs. Wright & Co., of Richmond, Va., quarried stone for bridge piers to be used in the construction of the Seaboard Air Line railway bridge over the Savannah river. No work of any consequence has been done since the bridge piers were quarried. The quarrying was limited to two openings within fifty yards of each other, which, from appearances, indicate that a considerable quantity of stone was quarried. The rock is remarkably uniform in color and grain, and entirely free from blemishes or imperfections of any character. It is intermediate, in color, grain and texture, between the Oglesby blue granite and the Swift and Wilcox light-gray granite; and it is a desirable stone, for either monumental or general architectural work, being susceptible of a high polish, and working well under the hammer. It resembles quite closely the Brewer rock, with the single exception of its containing somewhat larger and stouter plates of biotite.

The rock is a uniformly massive, fine-grained, medium blue-gray granite, in which the component minerals, feldspar, quartz and biotite, are easily discerned in the hand specimen. A thin section, under the microscope, shows a medium fine-grained biotite granite, composed of irregular grains of quartz, feldspar and biotite, intricately and closely interlocked. Orthoclase, the predominating feldspar, is associated with smaller amounts of microcline and plagioclase, characteristically twinned after the albite and pericline laws. Good cleavage and the simple type of Carlsbad twins characterize the orthoclase. Secondary chlorite and epidote, with prismatic inclusions of apatite and zircon; a few scattered grains of magnetite; and occasional intergrown foils of muscovite with the biotite comprise the remaining accessory minerals. The percentage of silica, 69.41 per cent., indicates a normal granite. The percentage loss on ignition is 0.48 per cent.

The sap (partially weathered granite) is quite thin, and is colored a slight yellow, which, from a microscopic examination, is due to partial decomposition of some of the biotite plates and, probably, of magnetite grains, by hydration and oxidation, forming the yellow colored hydrated oxide of iron.

THE HESTER PROPERTY. — This property is located one and a half miles N. 45° W. from Elberton, on the east side of the Elberton-Hartwell wagon-road. At several places, the rock outcrops as boulders over a somewhat steeply sloping hill-surface, about an eighth of a mile from, and east of the wagon-road. Other outcrops occur at the foot of the same hill, along the course of a small stream. An opening, of very slight dimensions, had been made in an outcrop occurring near the middle of the hill, where only a few slabs were taken out. The rock is intermediate, in grain, color and texture, between the Oglesby blue granite and the Swift and Wilcox light-gray stone, and is identical with the Adams stone. It is a homogeneous, medium-grained biotite granite, in which no imperfections are observable.

Studied under the microscope, a thin section of the rock reveals a medium-grained biotite granite, consisting of interlocking grains of quartz, feldspar and biotite with some intergrown muscovite. The usual feldspar species are present, with a preponderance of orthoclase. The biotite has altered to chlorite and epidote, in many cases.

Mr. T. J. Hester, of Elberton, is the owner of this property.

DR. CARLTON'S PROPERTY. — One and a quarter miles northeast of Elberton, on the northeast side of, and about one hundred yards from the Seaboard Air Line railway, are large boulder outcrops, extending over several acres of ground near the head of a very small stream. Two openings, near together and of slight dimensions, have been made; but only a small quantity of stone has been quarried.

This is a uniformly massive, fine-grained, medium blue-gray biotite granite, in which quartz, feldspar and biotite are readily determined by the unaided eye. A comparison of hand specimens of this and the Adams rock shows them to be the same in all respects. Several veins, varying from a half to one inch in width, and composed of large and well crystallized feldspar individuals, were observed in the more recent of the two openings. Under the microscope, the rock shows an aggregate of interlocking anhedra of feldspar, quartz and biotite, with scattered foils of muscovite. Orthoclase is the predominating feldspar. It displays good cleavage, and twinning after the Carlsbad law; also, intergrowths with another feldspar, as microperthite. Micropegmatitic structure of feldspar and quartz, variously intergrown, occurs somewhat abundantly. The rock is well adapted for monumental and general architectural work.

THE MARTIN PROPERTY.—About four miles a little north of east from Elberton, extensive outcrops of granite are reported to occur on the south side of the Seaboard Air Line railway, continuous in an almost east-and-west direction for a mile or more along the creek. The rock is further reported as having been worked near the railroad in several places, and used for railroad purposes. It is said to be a light-blue, fine-grained biotite granite, of good quality. It would appear from the description to be similar to the Adams and Carlton granites, with which it can probably be correlated.

THE OGLESBY AREA

Oglesby is a flag station on the Seaboard Air Line railway, seven miles west of Elberton. Within a radius of one and a half miles of Oglesby station, are half-a-dozen or more quarries, which represent the northeast extension from Oglethorpe county, of a very superior belt of fine-grained, dark-blue biotite granite, yielding a superb quality of stone for monumental and interior decorative work. This belt also traverses the extreme southeastern portion of Madison county. A general petrographic and geologic description of this belt as a whole will follow, in a subsequent chapter of this report. The Oglesby area is largely controlled and worked by "The Coggins Granite Company," of which Dr. N. G. Long, of Elberton, is President. The quarries belonging to this company were the only ones in operation at the time of the writer's field-study in this locality.

THE COGGINS GRANITE COMPANY'S QUARRIES

THE SWIFT AND ETHERIDGE QUARRY.—This quarry is not in the immediate vicinity of Oglesby; but it is located about three miles slightly north of east therefrom, and four miles S. 15° W. from Elberton, immediately on the southeast side of the Seaboard Air Line railway. A side-track, 1,650 feet long, is operated between the main line of the railroad and the quarry. The quarry is equipped with machinery for hoisting and handling the rock. The quarry tract, 34.4 acres, was purchased from Mr. C. F. Almand by Messrs. T. M. Swift and J. W. Etheridge, and was opened in 1893, when it was styled the Swift and Etheridge quarry. In 1897, it was purchased by Dr. N. G. Long, of Elberton. Subsequently, The Coggins Granite Company was chartered, with Dr. Long as President, and other quarries were acquired.

In the Swift and Etheridge quarry, there are some five acres of exposed rock, two of which have been stripped to a moderate depth, and, in places, worked down to a depth of 20 feet or more. A few joint-planes were found cutting the mass; but these are not sufficient to prevent profitable quarrying of large dimensional stone. The quarry is located in an outcrop, with an approximate surface slope of 25° toward the railroad, which facilitates easy and ready working. The rock is remarkably free from all blemishes and imperfections, and is a most desirable stone for monumental work.

The granite from this quarry is a shade lighter in color, than that quarried in the immediate vicinity of Oglesby. Based on this difference, the company designates the two granites as "Oglesby dark-blue" and "Oglesby light-blue" granite.

It is a very homogeneous, even, fine-grained biotite granite, possessing a uniform, dark blue-gray color. The component minerals, feldspar, quartz and biotite, are readily recognizable in the hand specimen.

Microscopically, the rock is a fine-, even-, compact-granular biotite granite, carrying considerable muscovite. In texture, it has a hypidiomorphic-granular tendency. It is composed of irregular grains of quartz, feldspar and biotite, and, in addition, a good quantity of muscovite, closely interlocking, thereby imparting great strength and resistance to the stone, which necessarily increases the durability proportionately. A sparse scattering of small grains of magnetite were occasionally observed in the thin section of the rock. The feldspar constituent consists almost entirely of microperthitic orthoclase and microcline, the orthoclase predominating. The latter shows good cleavage development, in most cases, and the simple type of Carlsbad twinning; while the characteristic gridiron structure is beautifully shown in the microcline crystals.

A chemical analysis of this rock yielded the writer the following results:—

Silica, SiO_2	70.38
Alumina, Al_2O_3	16.47
Iron Sesqui-oxide, Fe_2O_3	1.17
Lime, CaO	1.72
Magnesia, MgO	0.31
Soda, Na_2O	4.98
Potash, K_2O	5.62
Ignition	0.31
Total	100.96

A low percentage in the iron and magnesia constituents is indicated in the analysis, with a slight proportionate increase in the percentage of total alkalies and silica, for this rock.

Weathering.—The rock, where not worked, is discolored for several inches, from 3 to 10 inches in places, by the usual weathering to a light-red and yellowish-brown color. The decaying rock is converted into shelly layers or sheets, varying in thickness from a fraction to several inches. In some of these layers, the light-colored minerals, quartz and feldspar, show upon the surface next to the division plane, along which weathering has advanced most rapidly, somewhat of a porphyritic structure. No tendency, however, toward such structure can be observed in any portion of the fresh or unweathered rock. The soil derived from the decay of this rock is prevailingly red in color.

THE HILL QUARRY.—This quarry is located about one mile southwest of Oglesby, on the south side of, and about 75 paces from, the Seaboard Air Line railway. The opening is at the foot of a hill on a 200-acre tract, the right and privilege to all stone on which was purchased by Dr. N. G. Long, of Elberton, from Mr. A. P. Deadwyler. The granite outcrops as large boulders over the entire property, which is continuous to the North Fork of Broad river. The quarry is half-a-mile from the above stream, with its surface portion in rock-outcrops, of the boulder type, the removal of which reveals the continuous solid granite mass underneath. The rock is cut by two sets of joint-planes, with east-west and north-south directions. At the south end of the quarry, a zone, approximately ten feet in width, shows the rock to be cut up by a parallel east-west set of these planes. Since only one such zone in the quarry has thus far been encountered, they, by no means, interfere with getting out large dimensional stone, inasmuch as the planes intersecting other portions of the rock occur at such intervals, as to facilitate ready quarrying of almost any sized stone. A side-track is operated between the quarry and the main railroad line.

The quarry is equipped with hoisting derricks and drills, operated by steam, and a 40-H. P. engine, which admits of the easy handling of stone, of almost any dimension.

The stone is a fine-grained, dark-blue biotite granite, of excellent quality, and admirably adapted to monumental and interior decorative work. Magnetite is very sparingly present as microscopic grains, occurring in such minute quantities as to in-no-wise cause discoloration upon the stone's exposure to atmospheric agencies. No minerals, therefore, are present, that would be likely to have a deteriorating influence upon the rock.

Microscopically, the rock is a fine-, compact-grained biotite granite, with a somewhat hypidiomorphic-granular tendency in structure, and consists of an admixture of interlocking grains of quartz and feldspar with biotite folia, variously altered to chlorite and some epidote. Other accessories, such as, muscovite, zircon and apatite, are present in microscopic proportions. Orthoclase is the predominating feldspar species.

Specimens of the rock yielded the writer the following results upon chemical analysis in the Survey laboratory:—

Silica, SiO_2	69.64
Alumina, Al_2O_3	17.21
Iron Sesqui-oxide, Fe_2O_3	1.32
Lime, CaO	2.14
Magnesia, MgO	0.66
Soda, Na_2O	4.53
Potash, K_2O	4.95
Ignition	0.35
Total	100.80

The analysis shows essentially the same relative amounts per constituent, as that for the rock from the Swift and Etheridge quarry, except, that the percentage of lime is a little higher for this rock, indicating a larger amount of the soda-lime feldspars (plagioclase) present, which is confirmed by the microscope.

The quarry has been opened to a depth of probably forty feet. Along the face of the joint-planes, which serve as ready channelways for the free percolation of water, the rock has become partially weathered and discolored to a yellowish-red product, which scales off for a fraction to several inches in thickness, and extends to a depth equivalent to that, to which the quarry has been worked. The result of this process is as yet quite limited, extending merely along the surfaces of the boulders. The partially decayed product, when removed, reveals perfectly fresh and beautiful stone.

THE HILL QUARRY OF THE COGGINS GRANITE COMPANY, ON THE SEABOARD AIR-LINE RAILWAY, NEAR OGLESBY, GEORGIA.

THE COGGINS QUARRY. — This quarry is about one mile from, and opposite the Hill quarry, on the north side of the Seaboard Air Line railway. Ample facilities are provided for loading and shipping the stone from this point on the railroad, as well as that from the Venable and Collins and the Bisson quarries described below. The first work was done in 1882, when stone for chimneys and foundations was quarried. It was again worked in 1890 and 1891, for rock to be used in culvert construction along the Seaboard railway. A slight amount of work was done at intervals, from 1891 to 1897, by various parties, when the quarry passed into the hands of The Coggins Granite Company. It is estimated, that approximately 100,000 to 125,000 cubic feet of stone had been quarried, up to November, 1898. The tract, in which the quarry is located, includes nine acres, over which continuous boulder outcrops of granite extend.

The rock, where exposed by quarrying, is perfectly massive and uniform in color, grain and texture, without the slightest trace of blemish or imperfection of any character—a most superior monumental stone. It takes a high polish, works well under the hammer, and gives a striking contrast between the hammered and polished surfaces, which is a requisite for high grade monumental stock.

The study of a thin section under the microscope shows the component minerals, quartz and feldspar, with folia of biotite, all of which interlock in a most intricate and complex manner, imparting thereby great strength and durability to the stone. In texture, it is a fine- and even-grained biotite granite, in which orthoclase and microcline are the predominating species of feldspar. Accessory muscovite, apatite and zircon, and some chlorite, are present.

Chemical analyses of specimens of the fresh and the partially decomposed rock yielded the writer the following results: —

	I	II	III
Silica, SiO_2	69.74	67.92	60.94
Alumina, Al_2O_3	16.72	17.55	23.29
Iron Sesqui-oxide, Fe_2O_3	1.45	1.53	2.44
Lime, CaO	1.93	0.99	0.04
Magnesia, MgO	0.36	0.32	0.43
Soda, Na_2O	4.84	3.57	2.18
Potash, K_2O	5.33	5.43	3.57
Ignition	0.47	3.17	8.03
Total	100.84	100.48	100.92

I Fresh granite.
II Partially decayed granite.
III Partially decayed granite, representing a more advanced stage of decay than II.

Both the chemical analyses and the microscopic study reveal a smaller amount of the soda-lime feldspar species in this rock, than in that from the Hill quarry. The two, however, are identical in other respects.

The rock weathers in the same manner, as that from the Swift and Etheridge quarry and the Hill quarry, described above. The sap, which is the partially weathered portion, though still hard and firm rock, representing the outer portion of the stone, is very thin, and is discolored a yellowish-brown color, from the resulting partial decay of the biotite.

Assuming the iron oxide, in the case of the analyses in columns I and III to remain constant, and calculating the amounts lost and saved per each constituent in the rock, we find a total percentage loss for the entire rock, amounting to 44.52 per cent. This points to a predominance of chemical over physical forces in reducing the fresh rock to this stage of decay.[1]

Other tests made on specimens of the rock from this quarry gave the following figures: —

Specific gravity at 27° C.	2.84
Weight of one cubic foot of stone expressed in pounds	177.50
Number of cubic feet of stone in a ton (2,000 pounds)	10.7
Percentage (ratio) of absorption	0.090

These figures indicate, that the stone is capable of resisting, to a remarkable degree, the action of frost.

Resistance to chemical agencies is well brought out in the following: A weighed portion of the finely pulverized rock was treated for three hours at the temperature of boiling water, with 100 c.c. of half-normal hydrochloric acid, in a covered dish. This yielded 10.56 per cent. of soluble material. A partial quantitative analysis of this portion gave: —

Alumina, Al_2O_3 / Iron Sesqui-oxide, Fe_2O_3	4.05
Lime, CaO	0.53
Soda, Na_2O	0.57
Potash, K_2O	1.07
Total	6.22

THE BISSON QUARRY. — This quarry lies immediately across the wagon-road on the east side from the Coggins quarry. Mr. Peter Bisson purchased from Mr. A. P. Deadwyler, one acre, over which the rock outcrops as large boulders at the surface, to be worked up as monumental stock at his granite yard in Athens, Georgia. Practically, three of these boulders have been worked up.

[1] For a complete discussion on the weathering of the rock from this quarry, see Chapter V, Part 2.

The largest one is marked by white, wavy streaks, imparting something of a gneissoid structure to the rock. In a rough way, it somewhat resembles flow structure; but this is untenable, since the condition is decidedly a local one, in which the wavy areas of quartz and feldspar pass by imperceptible gradation into the blue granite, and can best be explained as a process of segregation or secretion. Wherever present, these areas render the rock undesirable for monumental stone; but it can be used as bases or rests for shafts. Field and microscopic study of the rock reveals the same uniformly fine-grained, compact blue biotite granite, as that quarried by the Coggins Granite Company at the Hill and the Coggins quarries, to which the reader is referred for detailed descriptions and analyses. It is composed of closely interknit grains of quartz, feldspar and biotite, with orthoclase as the predominating feldspar.

Physical tests made on this stone yielded the following results: —

Specific gravity at 19° C.	2.664
Weight of one cubic foot of stone expressed in pounds	166.50
Number of cubic feet of stone contained in one ton (2,000 pounds)	12.0

The Episcopal Church in Athens, Georgia, is built of this rock.

This quarry is now owned by The Coggins Granite Company.

THE DEADWYLER QUARRY.[1] — This quarry is located about one mile southwest from Oglesby, on the north side of, and about 1,900 feet from, the Seaboard Air Line railway. The tract includes about 30 acres, over which huge boulders outcrop at the surface. It was leased by Messrs. Venable and Collins from Mr. A. P. Deadwyler on a royalty, and was operated, from time to time, over a period of some two years. About 568 cubic yards of stone were stated to have been quarried by the Seaboard Air Line railway in 1891, for bridge piers along the road. This is but one of the many instances, where this superior and highly valued monumental stone has been made to serve in the place of a less desirable and lower grade material, which can be had at almost any point along the road from Atlanta to the Georgia-Carolina line. An opening has been made in the solid rock to a depth of 20 feet, or more, and a good quantity of stone has been quarried.

It is the same uniformly massive, fine-grained, dark-blue biotite granite, as that worked by the Coggins Granite Company at the

[1] Also known as the Venable & Collins quarry.

Hill and the Coggins quarries. Under the microscope, the rock is seen to be composed of an aggregate of interlocking anhedra of quartz and feldspar, with biotite folia variously intergrown with filaments of muscovite, and considerably changed to a dark, greenish, opaque chlorite and some epidote, and wholly without deteriorating accessories. Its texture is allotriomorphic-granular. Orthoclase predominates, with less microcline present than hitherto observed in the same rock from other quarries.

The rock, where opened, has been reduced, in some places, to the condition of a siliceous clayey soil, for a depth of half-a-dozen or more feet. The hard and firm, but partially decayed rock (sap) is quite thick in some instances, and is colored a light yellow. The outer portions of some of the boulders shell off, for several inches inward from the surface, into a perfectly kaolinized gray, and oftentimes red, ferruginous mass, which readily crumbles under gentle pressure or the blow of the hammer.

In the fresh rock, the biotite shows a tendency to collect in small specks, several millimeters in diameter, imparting somewhat of a porphyritic appearance, which is rather pleasing to the eye than otherwise, adding to, rather than detracting from, the stone, when polished. Not a blemish of any kind was observed. At the time of the writer's visit, derricks for handling the stone were in position.

Physical tests made on this stone yielded the following figures: —

Specific gravity at 18° C.	2.662
Weight of one cubic foot of stone expressed in pounds	166.37
Number of cubic feet of stone contained in one ton (2,000 pounds)	12.0

This quarry is now owned by The Coggins Granite Company.

THE CHILDS QUARRY. — Mr. L. D. Childs, of Chester, South Carolina, purchased from Mr. Abner Webb the right and privilege to all granite on 70 acres of land, lying on the southeast side of the Seaboard Air Line railway, and joining the "Coggins Granite Company's" property. Only one quarry has been opened. This is 800 yards east of the Coggins Granite Company's Hill quarry. The granite outcrops as boulders and sheets, or flat surfaces, over nearly the entire 70 acres, mostly as sheet outcrops, however. The rock is remarkably uniform in color, grain and texture, and is without the small specks of biotite described in the Deadwyler (Venable and Collins) quarry above; but it is badly cut by numerous veins composed almost entirely of quartz and feldspar, carrying usually a few large and stout plates of biotite, and, less frequently, plates of muscovite. The veins vary from a fraction of an inch to many inches in width. They necessarily cause considerable loss in quarrying; and the quarry was said to have been abandoned, on account of their number and extent. However, by the use of discretion and proper working, large dimension stone, of superior quality, can be obtained. The veins are known to the quarrymen as "white seams," which, from a color view-point, is a very apt term. The rock is an excellent one for monumental purposes.

A chemical analysis of specimens of the granite yielded the writer, in the Survey laboratory, the following results: —

Silica, SiO_2	69.36
Alumina, Al_2O_3	17.23
Iron Sesqui-oxide, Fe_2O_3	1.43
Lime, CaO	2.14
Magnesia, MgO	0.59
Soda, Na_2O	5.17
Potash, K_2O	4.57
Ignition	0.33
Total	100.82

Microscopically, the rock is made up of an admixture of closely interknit grains of feldspar and quartz, with irregular plates of biotite. Orthoclase is the most abundant species of feldspar present. It contains the same minerals, both essential and accessory, as the Coggins Granite Company's quarries described above, and merely represents an extension of the belt of blue granite. In texture, it is fine-grained and allotriomorphic-granular. It will be observed, from the chemical analysis and microscopic description, that this is a biotite granite, of the same kind and character as that described under the Coggins Granite Company's quarries and the Deadwyler (Venable and Collins) quarry.

Other tests made were —

Specific gravity at 18° C.	2.665
Weight of one cubic foot of stone expressed in pounds	166.56
Number of cubic feet of stone in one ton (2,000 pounds)	12.0
Percentage (ratio) of absorption	0.092

The weathering of this rock is, in all respects, similar to that, in the other quarries located in the Oglesby area.

MRS. P. DEADWYLER'S PROPERTY. — On the adjoining property to Mr. Webb from the south side, owned by Mrs. P. Deadwyler, are extensive outcrops of the same granite, in the nature of flat surfaces and boulders. As much as several acres of the stone is exposed in one continuous outcrop. The property is within one mile of the Seaboard Air Line railway.

Résumé

It is clearly evident from the foregoing descriptions of individual properties, that an inexhaustible supply of very superior grades of architectural granites, admirably adapted and well suited to general building, monumental and decorative purposes, exist in Elbert county. Rock has been obtained from numerous points throughout the area for local use, for the past 15 or 20 years; and a good quantity of stone has been quarried, of late years, at several places; but it can be safely said, that regular and systematic quarrying has scarcely begun.

The Oglesby blue granite area, by virtue of the excellent qualities of its stone, and its ready accessibility by railroad, bids fair to become one of the principal localities for high-grade monumental stone in this country. Its granite has already grown prominently in favor for this use, and each year the demand for this stock is increased. It possesses good working qualities under the hammer, and takes a high, uniform and even polish, with 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 to resist atmospheric agencies give it first rank as a monumental stone. The results of an examination of the rock in the natural outcrops, where it has been exposed for perhaps thousands of years, add further testimony to its durability and permanence. Notwithstanding the great period of time, during which this rock has been exposed, the decay is remarkably small.

The Elbert County granites are all homogeneous, massive rocks, varying from a light-gray to a dark blue-gray in color; from allotriomorphic- to somewhat hypidiomorphic-granular in texture; and from medium- to fine-, even-grained. They carry biotite as their chief accessory mineral, and are, therefore, biotite granites—*granitites*

Microscopically, they are composed of quartz, feldspar and biotite, the last variously altered to chlorite and some epidote, with microscopic proportions of muscovite, apatite, zircon and magnetite. The essential constituents, quartz and feldspar, are intricately and complexly interlocked, insuring strength and durability of the stone against the various disintegrating forces. Feldspar, quartz and biotite is the order of quantitative occurrence in these granites.

The feldspar constituent is invariably composed of the species, microperthitic orthoclase, microcline and plagioclase, named in order of their abundance. Their distinctive and characteristic optical properties render them readily distinguishable under the microscope. Twinning according to the several feldspar laws, and, in case of the orthoclase, a strong development of cleavage, are well marked. With the exception of plagioclase, the remaining species of feldspar and the quartz occur as allotriomorphic grains. Quartz and feldspar intergrowths, in the form of micropegmatitic structure, are very common to this rock. Biotite, as irregular, somewhat idiomorphic plates, is the chief accessory, and is always more or less altered to a dark, greenish, opaque chlorite, and, less frequently, to a slightly yellowish brown and pleochroic epidote. It is also, in nearly every instance, associated and intergrown with some foils and shreds of muscovite. Several other minerals commonly occur in microscopic proportions in this granite, chief among which are prismatic inclusions of apatite and zircon.

Chemically, the Elbert County granites are very closely related, indicating but slight variation in any one of the constituents determined. Whatever variation is noted is readily traceable to a corresponding variation in the essential minerals, such as a slight increase in the lime and soda contents, in some of the rocks over others, denoting a proportionate increase for the same rocks in the soda-lime feldspar—plagioclase. Analyses of the fresh rock from numerous localities in the county are here grouped, in order that comparison may be readily made, and variations in the constituents noted: —

	I	II	III	IV	V	VI	VII
Silica, SiO_2	69.64	69.74	70.38	69.36	69.45	69.25	71.00
Alumina, Al_2O_3	17.21	16.72	16.47	17.23	15.93	16.04	16.33
Iron Sesqui-oxide, Fe_2O_3	1.32	1.45	1.17	1.43	1.31	1.72	1.12
Lime, CaO	2.14	1.93	1.72	2.14	1.91	1.89	1.83
Magnesia, MgO	0.66	0.36	0.31	0.59	0.55	0.31	0.35
Soda, Na_2O	4.53	4.84	4.98	5.17	4.33	4.52	4.80
Potash, K_2O	4.95	5.33	5.62	4.57	5.16	4.94	4.65
Ignition	0.35	0.47	0.31	0.33	0.50	0.43	0.87
Total	100.80	100.84	100.96	100.82	99.14	99.10	100.95
Specific Gravity	——	2.84	——	2.665	2.652	——	——

Columns I, II, III and IV are analyses of rock from the Oglesby blue granite area.

Columns V, VI and VII are analyses of rock from the Elberton light-gray granite area.

One of the most important tests made was that, to determine the percentage (ratio) of absorption, which also conditions the stone's ability or power to resist frost action — freezing temperatures. The figures are—

I	Percentage (ratio) of absorption	0.090
II	" " " "	0.092
III	" " " "	0.090
IV	" " " "	0.096
V	" " " "	0.093

When we consider, that granites in general are capable of absorbing some two-tenths (0.2) of one per cent. of additional moisture, and that the figures given in the above table, in which the Elbert County granites show an absorption of less than one-tenth of one per cent., the natural conclusion is, that the ratio of absorption in the case of these granites is reduced to a minimum. The figures further indicate a compact, close-grained rock, in which the mineral constituents are firmly interlocked. For this reason, it will not be appreciably affected by frost action. The summation of the various physical, microscopical and chemical tests, together with a careful field examination of the natural rock outcrops in this county, reveals a high grade and superior stone, well suited in every way for the manifold uses, in which granite has been employed.

WILKES COUNTY

While Wilkes is adjoined on the north and west, respectively, by the largest granite-yielding counties in the State; still, comparatively few outcrops of granitic rock are known in the county, and practically no work has been done in the way of quarrying. About twelve miles northwest from Washington, the county-seat, in the neighborhood of Rayle Post-Office, several miles east of the Oglethorpe county-line, somewhat numerous outcrops of granitic rock are said to occur; but no quarrying has been undertaken. The only granite that has been worked lies several miles a little west of south from Washington.

THE PETTUS PROPERTY. — Located two miles a little west of south from Washington, on *lot No. 164*, belonging to Henry Pettus, colored, of Washington, is an outcrop of a boulder mass, less than an acre in extent, of a medium-gray and uniform-grained biotite granite, with a distinctly banded or gneissoid structure in some parts. The rock is generally massive in appearance; but it contains knotted areas, which display a slightly contorted tendency of the schistic layers. It is a very uniform and even-grained rock, of excellent quality. It has been used for a street and building

Fig. 1

Fig. 2

VIEWS IN THE COGGINS GRANITE QUARRY, OGLESBY, ELBERT COUNTY, GEORGIA.

Fig. 1 Shows the Decayed Dark-blue Granite Overlying the Fresh Rock.

Fig. 2 Illustrates the Spheroidal Weathering of the Granite.

stone in the town of Washington, Georgia. The quarry was first opened in 1896, and only a little work has been done. At the time of the writer's visit, the opening was filled with water. The soil, derived from this rock, is highly siliceous, porous and light-gray in color, and is well adapted to the cultivation of cotton.

One mile southwest from this opening, is a second outcrop of several acres of flat-surface rock, of the same character. In addition to the quartz, feldspar and biotite, some white muscovite and a few scattering garnets, of light-red color, were observed in the hand specimen.

Under the microscope, the rock reveals a rather coarse-grained texture, and is composed of quartz and feldspar, in which lie folia of biotite intimately associated with muscovite shreds. The feldspar consists of the species, microperthitic orthoclase, microcline and plagioclase. The orthoclase exhibits good cleavage, parallel to the base (001) and the clinopinacoid (010). The microcline shows the usual charactistic gridiron or twinned structure. A good sprinkling of plagioclase, marked by the polysynthetically twinned lamellæ, is present throughout the micro-section. The feldspars are partly altered to muscovite, calcite and kaolin, the remaining feldspathic material being almost opaque. The muscovite is especially noticeable, filling the cracks, along which the feldspathic alteration has progressed. Biotite is present as the chief accessory mineral, considerably altered to chlorite and large areas of epidote. Mechanical strain is shown by the presence of numerous microscopic fracture-planes crossing the quartz and feldspar individuals.

A chemical analysis of this rock, in the laboratory of the Geological Survey, yielded the writer the following results: —

Silica, SiO_2	74.64
Alumina, Al_2O_3	14.00
Iron Sesqui-oxide, Fe_2O_3	1.05
Lime, CaO	1.76
Magnesia, MgO	0.37
Soda, Na_2O / Potash, K_2O	7.77
Ignition	0.41
Total	100.00

The percentage of potash and soda in the above analysis was not estimated directly upon analysis; but it was calculated by difference. This may be compared with analyses of the granites and gneisses from the other counties, in which the close similarity is noted.

WARREN COUNTY

Warren county is located in the east-central part of the State, immediately northeast of Hancock county. It has its greater area north of the "fall-line", its southern portion consisting of the Coastal Plain sands and clays. Extensive areas of granite and gneiss occur, limited for the most part, to the east and central portions of the county. Apart from the small quantity of stone quarried for purely local use, practically no quarrying has been done.

THE HOLDER'S MILL AREA. — Eight miles northeast of Warrenton, the county-seat of Warren, and nine miles northwest of Thomson, the county-seat of McDuffie, at Holder's mill, is an extensive exposure of porphyritic gneissoid granite in the bed and along the course of Wrightsboro creek. The rock extends to the east and southeast for a mile or more along the east side of the stream, as numerous flat-surface and boulder outcrops. No opening had been made in the rock, and fresh specimens were difficult to obtain. A series of parallel dikes, composed of a very fine- and even-grained, medium-gray biotite granite, cuts the porphyritic rock, and may be seen to advantage, where the public road crosses the creek near the mill. The dikes average from four to six inches in width, and possess a marked laminated structure. The dikes and the porphyritic rock, through which they cut, afford excellent illustration of differential weathering in fine- and coarse-grained rocks. At every point examined, the dike surface stood nearly an inch above that of the porphyritic granite. The contact between the dikes and the porphyritic granite is very sharp. To the south and southeast of the granite-mass, the rock is a true mica-schist.

In the hand specimen, the rock is very coarse-grained; has a schistose or foliated structure; and is decidedly porphyritic in texture. The feldspar is the porphyritically developed constituent. The phenocrysts are from white-opaque to pink in color, and from 15 to 20 millimeters in length. They contain numerous biotite inclusions, and are frequently twinned according to the Carlsbad law. The rock shows an abundance of black biotite arranged along somewhat parallel lines. The constituent minerals, quartz, feldspar and biotite, are easily distinguished macroscopically.

Under the microscope, a thin section of the rock reveals a porphyritic granite, composed of quartz, the potash and lime-soda feldspars, and biotite. The phenocrysts are mostly orthoclase, with some microperthitic intergrowths, and a few crystals of microcline. The ground-mass consists of allotriomorphic grains of coarse-grained quartz and feldspar, in which lie stout plates of biotite. Orthoclase is the most abundant feldspar present. Plagioclase is fairly abundant in the ground-mass, giving extinction angles, on the twinned lamellæ, of from 11° to 13°. Biotite, as stout plates, of deep color and strong absorption, presents a parallel arrangement. Inclusions are common in the biotite and feldspars, and fracture-planes are numerous in the quartz and feldspar grains, indicating strain. Micropegmatitic intergrowths of quartz and feldspar occur.

THE BRINKLEY PLACE FLAT-ROCK.—Extensive outcrops of a coarse-grained porphyritic granite-gneiss, occur on the two sides of a small stream, four miles N. 20° E. from Warrenton, and one and three-quarter miles west from Camak. The rock begins to outcrop, as large boulders and ledges, along a steeply sloping hillside, about one hundred paces to the east of the public wagon-road, on the south side of the stream, and is continuous to within half-a-mile west of Camak. Several hundred yards distant from, and in the rear of, Mr. Brinkley's dwelling-house, is an exposure of approximately three acres of horizontal sheet-outcrop of this rock. On account of the extent and character of the outcrop at this point, the rock derives its name, "Flat-Rock." Outcrops continue, for some distance, along each road leading from the three-acre exposure.

On the northern side of the stream, in a cleared field, and in the rear of the Brinkley dwelling, the porphyritic granite-gneiss is cut by a dike of excellent dark-gray, even-, fine-grained biotite granite, 40 feet wide. The contact, made by the dike and the porphyritic granite-gneiss, is sharp and well defined, and is readily traceable on both sides of the dike. The dike rock becomes very much lighter in color, near the point of contact. This rock and the porphyritic granite-gneiss have essentially the same chemical and mineral composition, and differ only in texture and structure. While the granite of this dike is of excellent quality, there is no exposure of the dike, sufficient to permit an opinion as to the commercial value of its granite.

In the hand specimen, the porphyritic granite-gneiss has a distinctly foliated structure. The quartz and feldspar grains are drawn out, and enclosed by the biotite layers, forming, at times, distinct "augen" of these minerals. The rock carries an abundance of black biotite, arranged along parallel lines. Large white-opaque and pink porphyritic feldspar crystals, carrying numerous enclosed plates of biotite, occur. The quartz and feldspar grains are very often squeezed and drawn out, in the direction parallel with the biotite layers, as a result of metamorphic action.

Under the microscope, a thin section of the rock reveals a distinctly schistose porphyritic granite, composed of quartz, feldspar and biotite. The porphyritically developed minerals consist of the potash feldspars, which occur usually as large and irregularly developed phenocrysts, the largest of which exhibit a partial development of the microcline structure. These phenocrysts are embedded in a coarse-grained ground-mass, of quartz, feldspar and mica, arranged along somewhat roughly parallel lines. The feldspar content consists of the potash species, microcline and orthoclase, and some plagioclase. The larger crystals of feldspar enclose grains of quartz and biotite, and other feldspar species, which, for the most part, are rounded in outline, though, at times, some of the included feldspars assume somewhat elongated, prismatic outline. The quartz occurs variously interlocked with the feldspars, as coarse- and fine-grained mozaics. The finer mozaics of the two minerals clearly represent crushed zones surrounding the larger feldspar individuals, which, when taken in conjunction with the orientation of the biotite stringers, impart a schistose structure to the rock. The feldspar phenocrysts are badly fractured, which further indicates the strained condition, and points to the porphyritic structure, as the original structure of the rock. Twinning, according to the Carlsbad, albite and pericline laws, is frequently observed in the feldspar species. Micropegmatitic intergrowths of quartz and feldspar are very common. Biotite, with deep color and strong absorption, occurs as grouped shreds, arranged along more or less definitely parallel lines. It is variously altered to a dark, opaque chlorite, and occasional slightly pleochroic and strongly double-refracting epidote.

Chemical analyses of specimens of the fresh and the decayed rock from this locality, yielded the writer the following results: —

	I	II	III
Silica, SiO_2	66.31	56.40	68.38
Alumina, Al_2O_3	18.27	25.62	17.79
Iron Sesqui-oxide, Fe_2O_3	2.51	3.45	1.21
Lime, CaO	2.91	0.37	2.85
Magnesia, MgO	1.22	0.98	0.72
Soda, Na_2O	3.69	1.36	4.36
Potash, K_2O	4.09	2.99	3.57
Ignition	0.61	9.18	0.78
Total	99.61	100.35	99.66

I Analysis of the fresh porphyritic granite-gneiss.
II Analysis of the decayed porphyritic granite-gneiss.
III Analysis of the 40-foot granite dike, cutting the porphyritic granite-gneiss.

Recalculating the analyses, given under columns I and II, to a basis of 100, and assuming the alumina to remain constant in passing from the fresh to that stage of the decayed rock indicated in column II, a total loss for the entire rock is 34.04 per cent.

Weighed portions of the finely powdered fresh and decayed porphyritic granite-gneiss, indicated in columns I and II, when digested with boiling half-normal hydrochloric acid for three hours, yielded 16.29 per cent. and 23.67 per cent. of soluble matter, respectively.

The field and laboratory studies indicate, that this is the same rock as the one described above at Holder's mill, some four miles northeast of the Brinkley rock.

The rock finally weathers to a stiff red-and-white-mottled clay. The feldspar phenocrysts remain intact, as white clayey masses, embedded in the red clay, resulting from the decomposition of the groundmass minerals. The crystal outline of these decomposed phenocrysts is preserved in somewhat definite manner. An examination of the partially weathered surface-outcrops in the field invariably showed a weathering of the ground-mass or general rock-surface, to a depth of from a sixteenth to an eighth of an inch below that of the porphyritically developed feldspars.

THE ENGLISH QUARRY. — Two miles southeast of Warrenton, there is a flat-surface outcrop of fine-grained biotite granite in an old field. The outcrop includes approximately two acres of exposed rock. The rock can be worked with considerable ease, and is readily accessible. It was opened some years ago, when stone was quarried for the county-jail. No quarrying has been done since.

In the hand specimen, the rock is a medium light-gray, fine-grained, massive biotite granite. It shows a marked porphyritic tendency, with the porphyritically tending feldspars sometimes twinned according to the Carlsbad law, and usually displaying good cleavage development in two directions.

Under the microscope, a thin section indicates a fine-grained rock, composed of complexly interlocking quartz and orthoclase, with a paucity of microcline and plagioclase, and a small amount of biotite shreds. Orthoclase is the preponderating mineral present, with quartz next. In some cases, zonal and microperthitic structures are well developed, and the larger grains of the orthoclase usually enclose a considerable quantity of rounded quartz grains and biotite plates, with, less frequently, feldspar species and magnetite crystals. The plagioclase and microcline occur very sparingly in the thin section of the rock. The quartz occurs as small grains, filling the feldspar interspaces. Biotite is present as small ragged shreds, of green and brown color, with strong absorption in parallel polarized light; and it is much altered to chlorite, epidote and iron oxide. Apatite occurs as microscopic crystals.

At Rocky Ford branch, where the public wagon-road, leading from Warrenton, crosses the stream, there is a second rather extensive outcrop of the same rock, one and a half miles southeast of Warrenton, and one mile northwest from the English quarry. A large boulder outcrop of the same rock also occurs in the pine woods, just above and across the branch from Warrenton. So far as traced, the outcrops of this rock indicate a northeast-southwest trend for the granite area.

THE HILLMAN MATHEWS PROPERTY. — Located five and a half miles south of Thomson, and seven and a half miles east of Warrenton, are extensive boulder outcrops of a medium fine-grained, dark blue-gray biotite granite, having a slight porphyritic tendency, in places. It is estimated, that the boulder outcrops extend over 20 acres of the Mathews property. The only work done consists in a number of the larger boulders having been worked into pillars for dwelling-houses in the immediate neighborhood.

The rock, in the hand specimen, cannot be distinguished from that occurring on the English property. They have the same texture, color and grain, and exhibit alike a slight porphyritic tendency in some of the feldspars.

Under the microscope, a thin section of the Mathews rock indicates, as regards texture, mineral composition, occurrence and habit, identically the same rock as that from the English quarry, described above. In texture, the two rocks are allotriomorphic-granular, as contrasted with idiomorphic-granular. The essential difference consists in relatively somewhat larger amounts of plagioclase and microcline in the Mathews, than in the English rock.

A comparative study of the Mathews, and English rocks, made in the field and laboratory, shows them to be the same as that occurring one mile southwest of Thomson, in McDuffie county.

Three and a half miles south of Warrenton, on the two sides of the east-and-west wagon-road, on Mr. George Shirley's place, are boulder outcrops of a medium coarse-grained, reddish-gray porphyritic biotite granite. The porphyritic feldspar is deep pink in color, and from 5 to 10 millimeters long. It is frequently twinned according to the Carlsbad law, and displays good cleavages parallel to the base (001) and the clinopinacoid (010). The ground-mass feldspars are prevailingly white and opaque.

Microscopically, the rock has an allotriomorphic-granular texture, and is composed of quartz, the feldspars, plagioclase and orthoclase, and biotite. The quartz is present as large grains, occupying well defined areas, and considerably broken by lines of fracture. Plagioclase, showing small extinction angles in basal sections, is the predominant feldspar species present. It occurs as large, stout plates and irregular lath-shaped individuals. The largest individuals of plagioclase and orthoclase enclose smaller quartz grains and biotite foils. The feldspar, like the quartz, occupies definite areas and is crossed by numerous fracture lines. Zonal structure is well marked, and is quite common in the feldspar constituent. Only one small fragment of microcline, enclosed by a large plagioclase grain, was observed. The biotite usually occupies the areas between the quartz and the feldspar, as grouped plates and foils. It is deep brown in color, with strong absorption, and, to some extent, is altered to chlorite and epidote. Inclusions are quite common in the biotite. Considerable apatite, as microscopic crystals, is present.

Immediately on the north side of Taylor's creek, three miles south of Warrenton, and on the east side of the wagon-road, is a slight outcrop of the porphyritic granite, overlain by the fine-grained granite. At this point, the gradation from the one rock facies into the other is not altogether clear.

Rock, of the porphyritic facies, outcrops continuously from the Shirley field, for a distance of half-a-mile north. On the east side of the Louisville wagon-road, in a field, 100 yards from the exposure described above, are large boulder outcrops of the fine-grained granite, continuous, on the two sides of the road, to within one and a half miles south of Warrenton. The mica content in the granular facies of the rock is quite variable in quantity, from place to place.

The porphyritic rock, described from the Brinkley place and Holder's mill, four and a half and eight miles, respectively, from Warrenton, differs from that occurring three miles south of Warrenton, in being highly foliated and very much coarser in grain, and in carrying a larger amount of biotite. It is questionable, whether the two belong to the same period of intrusion. If so, the granular facies of the rock, which lies between the two porphyritic areas, might well represent a separate and later period of intrusion. Otherwise, the Brinkley place and Holder's mill rock must be considered older than the porphyritic and the granular facies of the rock, occurring in the areas to the south and east of Warrenton, which latter two represent the same period of intrusion, but owe their difference in texture to difference in conditions obtaining in separate portions of the same magma. The field and laboratory study more strongly point to the latter hypothesis, as being the more plausible one.

McDUFFIE COUNTY

McDuffie is bounded on the east and west by Columbia and Warren counties, respectively, and lies immediately south of Wilkes county, with its southern portion veneered with the Coastal Plain formations, which consist mostly of sands and clays. Only one area of granite is known in the county. This extends from near the Warren county-line to within half a mile southwest of Thomson, the county-seat. The rock outcrops in the form of boulders, and is a continuation of the fine-grained biotite granite in Warren county, on the Hillman Mathews place. Outcrops of the same rock occur between these two points.

The McDuffie-County jail at Thomson was built from rock obtained from the outcrop near Thomson. No fresh specimens of the rock could be obtained, on account of the rather advanced condition of weathering of the boulders. The weathered rock, still firm, presents a yellowish red stained surface, the result of oxidation of the biotite and the liberation of ferric oxide as the coloring matter.

In the northern part of the county, on the Murray place, seven and a half miles from the Columbia gold mine, along the Thomson-Raysville public road, is a flat-surface area of straight banded granite-gneiss, covering about three quarters of an acre. On the west side of the road, the area is more-or-less continuous in a westerly direction for half-a-mile, being exposed as large boulders along the branches and on the west side of the hill, where it was last observed, the masses, at this point, standing four or five feet above the surface. In an air-line, this area is about four miles northeast of the Columbia gold mine.

Along the same road, about three hundred yards north of the flat-surface outcrop on the Murray place, a smaller outcrop of this granite-gneiss occurs on either side of the road.

No attempt to work this area of valuable stone has so far been made.

COLUMBIA COUNTY

Columbia lies immediately east of McDuffie, and is separated from South Carolina on the east by the Savannah river. A veneer-

FIG. I. PHOTO-MICROGRAPH OF A PHENOCRYST OF PORPHYRITIC GRANITE, FROM EAST POINT, FULTON COUNTY, GEORGIA, SHOWING INCLUSIONS OF SOME OF THE GROUND-MASS MINERALS.
Crossed Nicols x 74.

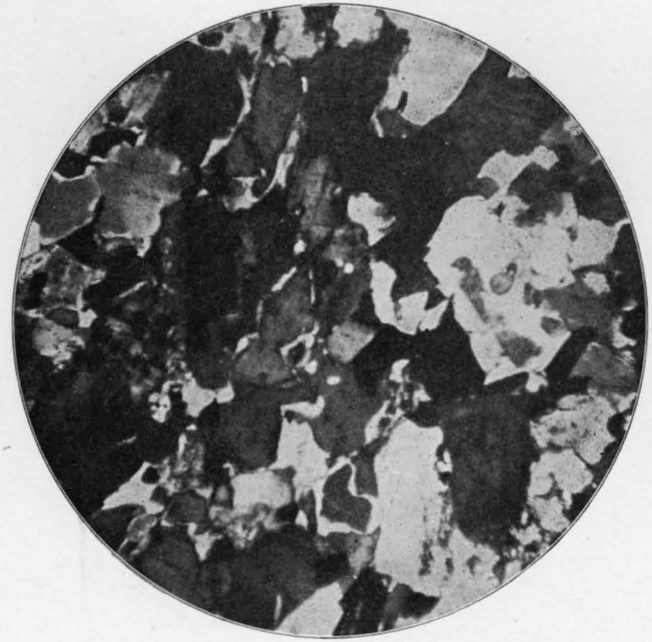


PHOTO-MICROGRAPH OF A FINE-GRAINED DARK-BLUE BIOTITE GRANITE, FROM THE FORTY-FOOT DIKE CUTTING THE PORPHYRITIC GRANITE-GNEISS NEAR CAMAK, WARREN COUNTY, GEORGIA.
Crossed Nicols x 74.

ing of the Coastal Plain sands and clays covers a large part of its southern portion. We have in this county an occurrence of granitic rock, very similiar to that described in Greene county, which is the fourth county in a due west course therefrom.

The central mass of granite is a typical porphyritic granite, with the outlying areas practically free from mica, and of the true granular texture, being composed chiefly of quartz and feldspar. The series is almost identical with that occurring in, and described from, Greene county; and hand specimens, representing the different facies from the two counties, are scarcely distinguishable, on comparison.

Along the public wagon-road, one and three-quarter miles east from Appling, the county-seat of Columbia, is an outcrop of porphyritic granite, the feldspars of which are pink or flesh in color, and, at times, of a more or less greenish cast. The blending of these with that of the black biotite present, gives rather a pleasing color to the rock.

In the hand specimen, the rock is composed of a close- but coarse-grained ground-mass of a dark vitreous quartz, flesh-colored feldspar and black biotite, in which are embedded pink feldspar phenocrysts, from 20 to 35 mm. long, and from 5 to 15 mm. broad, usually tabular parallel to the clinopinacoid (010), and commonly twinned according to the Carlsbad law. The cleavage-planes, parallel to the base (001) and clinopinacoid (010), are very distinctly marked. Enclosed folia of black biotite, of small dimensions, are readily recognized by the unaided eye, in most of the feldspar phenocrysts.

Microscopically, the rock is composed of a coarse-grained ground-mass of microperthitic orthoclase and plagioclase, and some microcline and quartz, with biotite and a few large plates of muscovite, in which are embedded large tabular microperthitic orthoclase phenocrysts. The quartz anhedra are variable in size and badly fractured. The phenocrysts of orthoclase contain abundant enclosed grains of all the ground-mass minerals, especially plagioclase and biotite, variously orientated. Plagioclase is rather abundant. The feldspars are more or less cloudy and opaque, from kaolinization. Micropegmatitic intergrowths of quartz and feldspar are sparingly present. Biotite, with the usual deep green and brown color and strong absorption, bearing in some cases numerous inclusions, is present as the chief accessory mineral, and is considerably altered to chlorite. Some large shreds of muscovite and a slight sprinkling of magnetite grains occur. Marked zonal structure is common to some of the feldspars.

The Heggie Rock[1]

Three miles east of Appling, and one and a quarter miles from the above described outcrop, is a large area of porphyritic granite, containing some fifty acres or more, exposed as a flat, dome-shaped mass, with a steep eastern erosion slope, due to stream action. The rock outcrops more or less continuously for a mile or more along each wagon-road, leading from the main porphyritic granite mass, and grades somewhat imperceptibly into a non-porphyritic, even-granular granite. The non-porphyritic, or even-granular, facies is best seen along the wagon-road, just above the Hicks's Branch crossing, opposite Smith's gin, three miles a little south of east from Appling. The belt averages from 400 to 500 yards in width, and is said to cross the county in an approximately northeast-southwest direction. It is apparently the same rock as that occurring at the Jackson place, in Greene county, and differs only from that occurring at Holder's mill and near Camak, in Warren county, in being massive, instead of schistose, in structure. No systematic quarrying has been done in Columbia county. Clusters or groups of cedar trees grow quite thick in places over the rock, from which fact, the main rock-mass is often referred to and known as "*Cedar Rock*." The principal outcrop of the rock is approximately six miles north from the nearest railroad point on the Georgia railroad.

In the hand specimen, the rock cannot be distinguished from the similar one described above, from the outcrop along the wagon-road, one and three-quarter miles east of Appling. It is a coarse-grained porphyritic granite. The tabular-shaped feldspar phenocrysts measure from 30 to 40 mm. in length, and from 5 to 15 mm. in width. They possess marked cleavage, parallel to the base (001) and the clinopinacoid (010). They are twinned according to the Carlsbad law, and have a decided pink or flesh color. A thin section of one of the phenocrysts proved, under the microscope, to be the potash feldspar, microcline. The complexly twinned gridiron structure is not strongly and uniformly developed throughout the individual crystal; but it is, for a number of parts of the crystal, characteristically developed, when seen under crossed nicols. It contains a large number of enclosed grains of all the ground-mass minerals variously orientated with reference to the cleavage directions.

[1] Also known as Cedar Rock.

A chemical analysis of fragments, carefully selected from the phenocrysts of this rock, gave the writer the following results: —

Silica, SiO_2	64.64
Alumina, Al_2O_3	19.64
Iron Sesqui-oxide, Fe_2O_3	0.37
Lime, CaO	0.67
Magnesia, MgO	trace
Soda, Na_2O	3.06
Potash, K_2O	10.00
Ignition	0.22
Total	98.60
Specific Gravity	2.60

The large porphyritic feldspar crystals are embedded in a close- and firm-textured, but coarse-grained ground-mass, composed of flesh-colored feldspar, with, in some instances, a slightly greenish cast; somewhat dark-colored, but highly vitreous, quartz; and black biotite. The porphyritic crystals will make up nearly one-half of the total rock-mass. Feldspar, including all species present, is greatly in excess of any other mineral in the rock. Over a large portion of this area, however, the feldspars are wholly without pink and greenish tints, and are decidedly white and opaque. The rock, in the hand specimen, cannot be distinguished from that occurring in Greene county, described elsewhere in this report.

Microscopically, this is a coarse-grained porphyritic granite, composed of an admixture of quartz and feldspar, with aggregated intergrowths and single shreds and folia of biotite, as the characterizing accessory. Large porphyritic crystals of orthoclase, containing inclusions of all the ground-mass minerals, without orientation, are embedded in a coarse-grained groundmass composed of the different feldspars interlocked with quartz and biotite. Some of the largest lath-shaped plagioclases, included in the orthoclase phenocrysts, carry, in turn, microscopic inclusions of quartz and other minerals. A number of the enclosed feldspars in the porphyritic mineral are twinned after the Carlsbad law. The enclosed plagioclase grains display the characteristic polysynthetic twinned lamellæ. The biotite is from green to brown in color, in parallel polarized light, and presents the usual optical characteristics. It is somewhat altered to chlorite and epidote. Some intergrown shreds of muscovite, with the biotite, and a few scattered grains of magnetite, occur in microscopic proportions.

Chemical analyses of specimens of the fresh and the partially decomposed granite yielded the writer the following results: —

	I	II
Silica, SiO_2	69.77	67.87
Alumina, Al_2O_3	17.05	18.08
Iron Sesqui-oxide, Fe_2O_3	1.60	1.91
Lime, CaO	2.21	2.28
Magnesia, MgO	0.99	0.79
Soda, Na_2O	3.97	4.32
Potash, K_2O	4.08	4 52
Ignition	0.44	0 63
Total	100.11	100.40

I Analysis of the fresh porphyritic granite.
II Analysis of the partially decomposed porphyritic granite.

Re-calculating the analyses in the two columns above, and assuming the iron oxide to remain constant, a total percentage loss for the entire rock, of 15.84 per cent., results, in passing from the condition of fresh rock to the stage of decay represented by the analysis in column II. This indicates, that the fresh rock crumbles to a coarse granitic sand, in which each of the essential minerals, quartz, feldspar and biotite, occur in a partial state of preservation through the operation of both chemical and physical forces.

A weighed portion of the finely pulverized fresh granite yielded, after digestion for three hours with boiling half-normal hydrochloric acid, 10.98 per cent. of soluble matter. Similar treatment of a weighed portion of the finely powdered partially decayed granite, represented by the analysis in column II, gave 12.69 per cent. of soluble matter.

Other tests made on specimens of this granite gave the following figures: —

Specific Gravity at 28° C.	2.674
Weight of one cubic foot of stone expressed in pounds	166.87
Number of cubic feet of stone contained in one ton (2,000 pounds)	11.9

A specimen of the rock collected near Hicks's branch, opposite the gin along the wagon-road, and three miles east of Appling, shows a granite, of medium grain, consisting of dark smoky quartz and white-opaque, granular feldspar, with a small quantity of minute folia of black biotite scattered through the rock-mass. The quartz grains measure from 3 to 5 mm. in diameter. This mineral is next to feldspar in abundance. The areas, surrounding the mica flecks, are somewhat discolored, from a partial decomposition of the biotite. The granite is in every respect similar to that occurring along the wagon-road, two and a half miles northwest of the porphyritic granite area in Greene county; and the two weather in precisely the same manner.

The gradation from the porphyritic to the non-porphyritic granular facies is equally as striking in this, as in the Greene County area, described elsewhere in this report.

RICHMOND COUNTY

With the exception of a very small area in the northeastern part of Richmond county, almost its entire surface is covered by the Coastal Plain sediments, consisting of sands, clays etc. The outcrops of the crystalline rocks are limited, therefore, to the above restricted area. The county is separated from South Carolina on the east by the Savannah river. Thus far, only one outcrop of granitic rock in the county is known to the writer. This is seven miles north of Augusta, near the head of the canal, at the locks. The exposure reveals a contorted biotite granite-gneiss along the face of a cliff, from 100 to 150 feet in height, which forms the western side of the Savannah river at this point. Some of the rock has been used for rough work. The rock is a vari-colored biotite granite-gneiss, becoming massive granitic in some places. It has no value, save for the rougher grades of work, such as the building of roads, dams, retaining-walls etc.

A thin section, under the microscope, reveals a medium coarse-grained rock, composed of quartz, orthoclase, plagioclase, microcline and biotite, the last named being considerably altered to chlorite. The structure is massive-granular, without any parallel arrangement of the mineral constituents shown. The quartz is the predominating mineral. It occurs as large anhedra, greatly crushed and shattered into a fine-grained, interlocking mozaic, occupying at all times, large and well defined areas. More-or-less feldspar nearly always occurs interlocked and mixed with the small- and crushed-grained mozaics of quartz. Orthoclase and plagioclase are present in approximately equal proportions, with but little microcline observed. Twinning, zonal and occasional microperthitic structures are common to some of the feldspar species. The quartz and feldspar frequently occur intergrown. Biotite occurs as small shreds, of green and brown color, and greatly altered. The essential minerals interlock in an intricate manner, and furnish no evidence of other than an igneous rock.

About half-a-mile to the south, and on the same side of the canal, is an extensive vertical exposure of quartzite, highly schistose in structure, and cut by innumerable joint-planes at right-angles to the schistosity, causing the rock to break into very small pieces. This material is a very fine rock for road-metal, and has been extensively worked for that purpose.

CHAPTER IV

THE GENERAL CHEMICAL AND LITHOLOGICAL CHARACTERISTICS OF THE GEORGIA GRANITIC ROCKS[1]

CHEMICAL COMPOSITION

The Georgia granites show more or less variation in texture and structure, in the different localities studied. They may be grouped accordingly, as (a) normal granites, (b) porphyritic granites and (c) granite-gneisses. The three types are usually well differentiated in the areas, where typically developed, and are quite sharp; but the normal granites and their porphyritic facies, with few exceptions, grade into each other, in almost every locality studied.

In chemical composition, the three groups show remarkably close agreement, and are very similar to the granites from other localities in the United States. From an examination of the accompanying tables of analyses of the Georgia granites, it will be observed, that their most distinguishing feature is their relatively high percentage of soda, which is above the average for normal granites. The soda and potash contents approximate nearly equal percentage amounts in a majority of the analyses; but, in some, the potash exceeds the soda; while, in others, the soda is in considerable excess over the potash. This condition is undoubtedly due, principally to the presence of comparatively large amounts of the plagioclase feldspars, the soda and soda-lime species. In the case of the porphyritic granites, however, analyses were made of the potash feldspar phenocrysts occurring in two of the widely separated porphyritic areas, with the result, that approximately one-third of the potassium is found replaced by sodium in the orthoclase-microcline molecule. The following are

[1] Watson, Thomas L., The Granitic Rocks of Georgia and Their Relationships, Amer. Geologist, 1901, Vol. XXVII, pp. 199–225.
Ibid., On the Origin of the Phenocrysts in the Porphyritic Granites of Georgia, Jour. of Geology, 1901, Vol. IX, pp. 97–122.

analyses of the potash porphyritic feldspars (phenocrysts) carefully selected from hand-specimens of two widely separated porphyritic areas: —

	McCollum Quarry Coweta County	The Heggie Rock Columbia County
Silica, SiO_2	64.40	64.64
Alumina, Al_2O_3	18.97	19.64
Iron Sesqui-oxide, Fe_2O_3	0.37	0.37
Lime, CaO	0.59	0.67
Magnesia, MgO	trace	trace
Soda, Na_2O	3.60	3.06
Potash, K_2O	11.40	10.00
Ignition	0.19	0 22
Total	99.52	98.60

It will be observed, from the above analyses, that the orthoclase molecule, $KAlSi_3O_8$ (K_2O, Al_2O_3, $6SiO_2$) is not a straight potash molecule; but, instead, the potassium is replaced in part by sodium. This undoubtedly becomes, in part, another source for the amount of sodium. Still another source, shown in the microscopic study of the rocks, is found in the abundant microperthitic structure (albite intergrowths), common to the potash feldspars in the three granite types.

An average of twenty, ten and twelve analyses of the normal granites, porphyritic granites and granite-gneisses, respectively, gave the following mean percentages of soda and potash: 4.73 per cent. Na_2O and 4.71 per cent. K_2O, for the normal granites; 4.33 per cent. Na_2O and 4.59 per cent. K_2O, for the porphyritic granites; and 4.16 per cent. Na_2O and 4.63 per cent. K_2O, for the granite-gneisses. These figures show remarkable uniformity in the soda and potash contents for the above groups of granite rocks; but an examination of the individual analyses reveals in many cases a greater variation. The general 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 gneisses to 9.44 per cent. in the granites.

Many of the granites from the Eastern, Middle Western and Northwestern United States are closely analogous to the Georgia granites, in showing a larger percentage of soda, than is in the normal granite.

With only a few exceptions, the Georgia rocks are normally acid granites, showing a general average of approximately 70 per cent. of silica. A mean of 69.67 per cent. of silica was obtained from an average of twenty-one analyses of the even-granular granites, in which 72.56 and 68.38 represented the maximum and minimum percentages of silica. In like manner, an average of ten analyses of the porphyritic granites yielded a mean of 69.28 per cent. of silica, in which the maximum and minimum percentages for this constituent were 70.90 and 66.31. Likewise, an average of twelve analyses of the gneisses, with the two extremes represented by 76.37 per cent. and 68.89 per cent. of silica, gave a mean of 73.76 per cent. It will be observed, therefore, from a comparison of these figures, that the normal granites and their porphyritic facies show practically no appreciable difference in the silica content, as would be expected; while the granite-gneisses are slightly more acid, and range from three to four per cent. higher in this constituent. This relationship in the silica content is almost equally as well shown, when a comparison of the individual analyses of the several groups is made.

The alumina, as in the case of the silica, remains very uniform throughout, and shows but slight variation. As may be seen from the analyses below, it is approximately the same for the porphyritic and non-porphyritic granite facies; but it is about two per cent. less for the gneisses. An average of twenty-one analyses of the normal granites gave a mean, for this constituent, of 16.63 per cent.; ten analyses of the porphyritic granite facies gave 16.73 per cent.; and twelve analyses of the granite-gneisses gave a mean of 14.52 per cent.

The percentages of iron and magnesia are somewhat below the general average for normal granites. The percentage of iron shows close agreement throughout the groups. A general average gave 1.03 per cent. of iron sesqui-oxide for the granite-gneisses; 1.28 per cent. for the even-grained granites; and 1.75 per cent. for the porphyritic granites. The magnesia shows greater variation in the separate analyses; but it averages considerably under one per cent. for each of the three types. The average is, for the normal granites, 0.55 per cent.; for the porphyritic granites, 0.72 per cent.; and for the granite-gneisses, 0.29 per cent. of magnesia.

As was observed in the case of the silica and alumina, the percentage of lime remains practically constant in the mean averages of the two granite facies, porphyritic and non-porphyritic; but it shows a decrease of nearly one-half for the granite-gneisses. The average percentages of lime are, for the even-grained granites, porphyritic granites and granite-gneisses, 2.16, 2.13 and 1.14, respectively. The smaller percentage of lime in the granite-gneisses is directly traceable to a smaller proportion of lime-soda feldspar than is in the two granite facies.

The above figures, with their corresponding molecular ratios, are summed up below in tabular form, for sake of easy comparison.

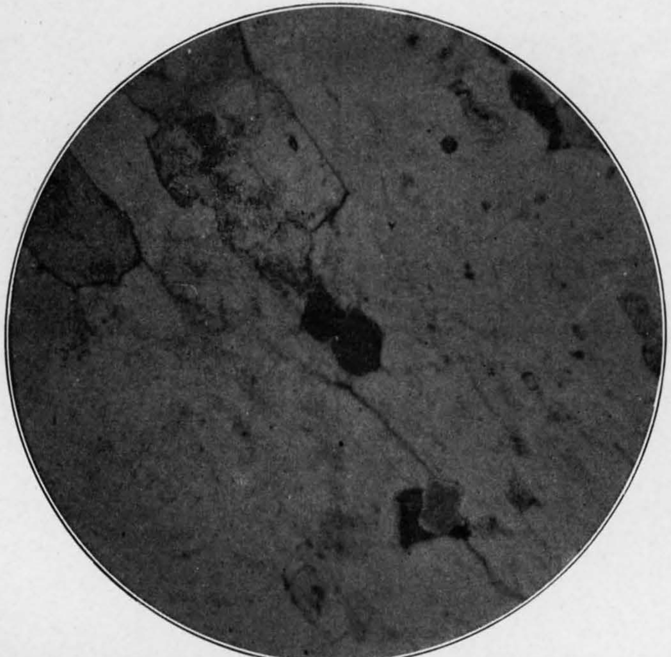


FIG. 1. PHOTO-MICROGRAPH OF PORPHYRITIC GRANITE, FROM THE COLUMBIA COUNTY AREA, NEAR APPLING, GEORGIA.
Crossed Nicols x 74.

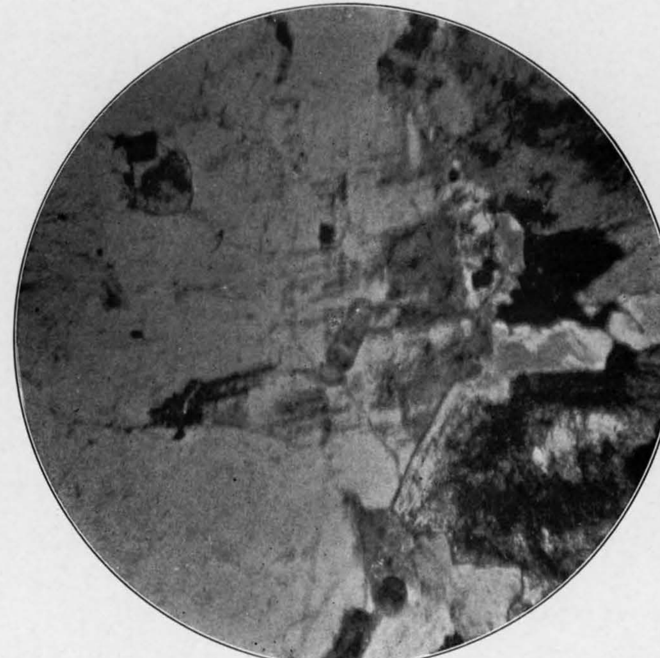


FIG. 2. PHOTO-MICROGRAPH OF A MICROCLINE PHENOCRYST OF THE GRANITE OF FIG. 1, SHOWING INCLUSIONS OF SOME OF THE GROUND-MASS MINERALS.
Crossed Nicols x 74.

Constituents	Normal Granites[1]	Porphyritic Granites[2]	Granite-Gneisses[3]
Silica, SiO_2	69.67	69.28	73.76
	1.161	**1.154**	**1.229**
Alumina, Al_2O_3	16.63	16.73	14.52
	.163	**.164**	**.142**
Iron Sesqui-oxide, Fe_2O_3	1.28	1.75	1.03
	.008	**.010**	**.006**
Lime, CaO	2.13	2.16	1.14
	.038	**.038**	**.020**
Magnesia, MgO	0.55	0.72	0.29
	.013	**.018**	**.007**
Soda, Na_2O	4.73	4.33	4.16
	.076	**.069**	**.067**
Potash, K_2O	4.71	4.59	4.63
	.050	**.048**	**.049**

CHEMICAL ANALYSES OF THE GEORGIA GRANITES

	I	II	III	IV	V	VI	VII	VIII
SiO_2 . .	72.56	71.00	70.38	70.30	70.18	70.03	69.88	69.74
	1.209	**1.183**	**1.173**	**1.171**	**1.169**	**1.167**	**1.164**	**1.164**
Al_2O_3 .	14.81	16.33	16.47	16.17	17.30	15.62	16.42	16.72
	.145	**.160**	**.161**	**.158**	**.169**	**.153**	**.160**	**.163**
Fe_2O_3 .	0.94	1.12	1.17	1.19	1.20	1.31	1.96	1.45
	.005	**.007**	**.007**	**.007**	**.007**	**.008**	**.012**	**.009**
CaO . .	1.19	1.83	1.72	2.61	2.03	2.45	1.78	1.93
	.021	**.032**	**.030**	**.046**	**.036**	**.043**	**.032**	**.034**
MgO . .	0.20	0.35	0.31	0.31	0.64	0.52	0.36	0.36
	.005	**.008**	**.007**	**.007**	**.013**	**.013**	**.009**	**.009**
Na_2O .	4.94	4.80	4.98	4.72	4.36	4.22	4.45	4.84
	.079	**.077**	**.080**	**.078**	**.070**	**.080**	**.071**	**.078**
K_2O . .	5.30	4.65	5.62	4.88	4.77	5.42	5.63	5.33
	.056	**.049**	**.059**	**.051**	**.050**	**.057**	**.059**	**.056**
Igni. . .	0.70	0.87	0.31	0.63	0.35	0.77	0.39	0.47
Total .	100.64	100.95	100.96	100.81	100.83	100.94	100.87	100.84

	IX	X	XI	XII	XIII	XIV	XV	XVI
SiO_2 . .	69.64	69.55	69.53	69.45	69.36	69.34	69.25	69.08
	1.160	**1.159**	**1.158**	**1.157**	**1.156**	**1.155**	**1.154**	**1.151**
Al_2O_3 .	17.21	16.72	16.46	15.93	17.23	17.01	16.04	17.67
	.168	**.163**	**.161**	**.156**	**.168**	**.166**	**.157**	**.173**
Fe_2O_3 .	1.32	0.99	1.15	1.31	1.43	1.74	1.72	1.41
	.008	**.006**	**.007**	**.008**	**.008**	**.010**	**.010**	**.008**
CaO . .	2.14	1.69	2.10	1.91	2.14	2.77	1.89	3.27
	.038	**.030**	**.037**	**.034**	**.038**	**.049**	**.033**	**.058**
MgO . .	0.66	0.27	0.85	0.55	0.59	0.61	0.31	0.64
	.016	**.006**	**.021**	**.013**	**.014**	**.015**	**.007**	**.013**
Na_2O .	4.53	5.88	5.00	4.33	5.17	4.69	4.52	4.56
	.073	**.094**	**.080**	**.069**	**.083**	**.075**	**.072**	**.073**
K_2O . .	4.95	3.94	4.91	5.16	4.57	4.54	4.94	3.29
	.052	**.041**	**.052**	**.054**	**.048**	**.048**	**.052**	**.035**
Igni. . .	0.35	0.27	0.91	0.50	0.33	0.26	0.43	0.56
Total .	100.80	99.31	100.91	99.14	100.82	100.96	99.10	100.48

[1] Average of 21 analyses. [2] Average of 10 analyses. [3] Average of 12 analyses.

	XVII	XVIII	XIX	XX	XXI	XXII	XXIII
SiO_2 . . .	69.07	68.81	68.79	68.76	68.38	66.92	63.27
	1.151	**1.146**	**1.146**	**1.146**	**1.139**	**1.115**	**1.054**
Al_2O_3 . .	16.56	17.67	16.48	16.80	17.79	18.19	19.93
	.162	**.173**	**.161**	**.164**	**.174**	**.178**	**.195**
Fe_2O_3 . .	1.37	1.13	0.98	0.99	1.21	3.05	2.82
	.008	**.007**	**.006**	**.006**	**.007**	**019**	**.017**
CaO . . .	1.83	2.17	1.76	2.72	2.85	4.95	2.89
	.032	**.038**	**.031**	**.048**	**.050**	**.088**	**.051**
MgO . . .	0.76	0.50	1.30	1.00	0.72	1.25	0.49
	.019	**.012**	**.032**	**.025**	**.017**	**.031**	**.012**
Na_2O . . .	4.65	4.97	4.74	4.82	4.36	3.83	4.14
	.075	**.080**	**.076**	**.077**	**.070**	**.061**	**.066**
K_2O . . .	5.02	3.90	5.85	3.70	3.57	2.02	4.85
	.053	**.041**	**.062**	**.039**	**.037**	**.021**	**.051**
Igni. . . .	0.92	0.30	0.38	0.29	0.78	0.46	0.86
Total . .	100.18	99.45	100.28	99.08	99.66	100.67	99.25

CHEMICAL ANALYSES OF THE GEORGIA PORPHYRITIC GRANITES.

	XXIV	XXV	XXVI	XXVII	XXVIII	XXIX
SiO_2	70.90	70.88	70.24	69.77	69.48	69.37
	1.181	**1.181**	**1.170**	**1.162**	**1.158**	**1.156**
Al_2O_3	15.86	15.86	16.78	17.05	16.64	16.99
	.155	**.155**	**.164**	**.167**	**.163**	**.166**
Fe_2O_3	1.37	1.77	1.46	1.60	1.84	1.99
	.008	**.011**	**.009**	**.010**	**.011**	**.012**
CaO	2.15	1.79	2.00	2.21	2.32	2.03
	.038	**.032**	**.035**	**.039**	**.041**	**.036**
MgO	0.02	0.93	0.76	0.99	0.29	0.84
	.001	**.023**	**.019**	**.024**	**.007**	**.021**
Na_2O	5.05	3.94	3.70	3.97	4.74	3.44
	.081	**.063**	**.059**	**.064**	**.076**	**.055**
K_2O	4.62	4.64	5.03	4.08	4.49	4.54
	.049	**.049**	**.053**	**.043**	**.047**	**.048**
Igni.	0.50	0.49	0.50	0.44	0.46	0.55
Total	100.47	100.30	100.47	100.11	100.26	99.75

	XXX	XXXI	XXXII	XXXIII	XXXIV
SiO_2	69.17	69.13	67.62	66.31	63.65
	1.152	**1.152**	**1.127**	**1.105**	**1.060**
Al_2O_3	16.47	17.14	16.29	18.27	20.46
	.163	**.168**	**.159**	**.179**	**.200**
Fe_2O_3	1.22	1.52	2.31	2.51	2.20
	.007	**.009**	**.014**	**.015**	**.013**
CaO	2.02	1.85	2.37	2.91	3.38
	.036	**.033**	**.042**	**.052**	**.060**
MgO	0.61	0.79	0.78	1.22	1.50
	.015	**.019**	**.019**	**.030**	**.037**
Na_2O	4.89	4.06	5.42	3.69	4.75
	.078	**.065**	**.090**	**.059**	**.076**
K_2O	4.41	5.49	4.58	4.09	4.58
	.047	**.058**	**.048**	**.043**	**.048**
Igni.	1.06	0.52	0.32	0.61	0.42
Total	99.85	100.50	99.69	99.61	100.94

CHEMICAL ANALYSES OF THE GEORGIA GRANITE-GNEISSES

	XXXV	XXXVI	XXXVII	XXXVIII	XXXIX	XL
SiO_2	76.37	76.00	75.89	75.45	75.16	74.96
	1.272	**1.266**	**1.264**	**1.257**	**1.252**	**1.249**
Al_2O_3	13.31	13.11	14.02	13.71	13.74	13.71
	.130	**.128**	**.137**	**.134**	**.134**	**.134**
Fe_2O_3	1.21	0.92	0.71	0.92	0.91	0.90
	.007	**.005**	**.004**	**.005**	**.005**	**.005**
CaO	1.13	1.06	0.70	0.94	0.91	1.02
	.020	**.018**	**.012**	**.016**	**.016**	**.018**
MgO	0.10	0.27	0.12	0.18	0.17	0.24
	.002	**.006**	**.003**	**.004**	**.004**	**.006**
Na_2O	4.02	3.88	3.64	3.87	3.76	4.68
	.064	**.062**	**.058**	**.062**	**.060**	**.075**
K_2O	3.68	4.69	5.56	4.30	5.05	4.79
	.039	**.049**	**.059**	**.045**	**.053**	**.050**
Igni.	0.20	0.31	0.28	0.40	0.32	0.44
Total	100.02	100.24	100.92	99.77	100.02	100.74

	XLI	XLII	XLIII	XILV	XLV	XLVI
SiO_2	74.80	73.95	72.96	71.20	69.51	68.89
	1.246	**1.232**	**1.216**	**1.186**	**1.158**	**1.149**
Al_2O_3	15.46	14.23	14.70	15.46	16.32	16.47
	.151	**.139**	**.144**	**.151**	**.160**	**.161**
Fe_2O_3	1.04	1.29	1.28	1.17	2.38	2.34
	.006	**.008**	**.008**	**.007**	**.014**	**.014**
CaO	0.82	1.07	1.28	1.36	1.84	1.63
	.014	**.019**	**.022**	**.024**	**.032**	**.029**
MgO	0.11	0.23	0.07	0.38	1.28	0.40
	.002	**.005**	**.001**	**.008**	**.032**	**.010**
Na_2O	4.80	4.61	4.18	4.96	3.82	4.38
	.077	**.074**	**.067**	**.080**	**.061**	**.070**
K_2O	2.52	5.29	4.73	5.30	3.47	4.15
	.026	**.056**	**.050**	**.056**	**.036**	**.044**
Igni.	0.31	0.25	0.23	0.52	1.11	0.32
Total	99.86	100.92	99.43	100.35	99.73	98.58

I Biotite-bearing muscovite granite, from Stone Mountain, DeKalb county.

II Biotite granite, from the Fortson quarry, near Goss, Elbert county.

III Biotite granite, from the Swift and Etheridge quarry (Coggins Granite Co.), 4 miles from Elberton, Elbert county.

IV Biotite granite, from the Diamond Blue Granite Company's quarry, near Hutchins, Oglethorpe county.

V Biotite granite, from the Brown-Deadwyler quarry, Madison county.

VI Biotite granite, from the Lexington Blue Granite Company's quarry, Oglethorpe county.

VII Biotite granite, from the Greenville Granite Company's quarry, Meriwether county.

VIII Biotite granite, from the Coggins quarry, near Oglesby, Elbert county.

IX Biotite granite, from the Coggins Granite Company's Hill quarry, near Oglesby, Elbert county.

X Biotite granite, from the Carmichael quarry, near Fairburn, Campbell county.

XI Biotite granite, from an average of several openings, near Hutchins, Oglethorpe county.

XII Biotite granite, from the Swift and Wilcox quarry, near Elberton, Elbert county.

XIII Biotite granite, from the Childs quarry, near Oglesby, Elbert county.

XIV Biotite granite, from the Linch quarry, near Eatonton, Putnam county.

XV Biotite granite, from the Tate and Oliver quarry, Elberton, Elbert county.
XVI Biotite granite, from the Cole quarry, near Newnan, Coweta county.
XVII Biotite granite, from the Overby quarry, Coweta county.
XVIII Biotite granite, from Echols' Mill, Oglethorpe county.
XIX Biotite granite, from the Sam Hill quarry, near Newnan, Coweta county.
XX Biotite granite, from the Turner quarry, Griffin, Spalding county.
XXI Biotite granite, from the 30-foot dike, near Camak, Warren county.
XXII Grano-diorite gneiss, from near Grantville, Coweta county.
XXIII Biotite granite, from the Tigner quarry, near Odessa, Meriwether county.
XXIV Porphyritic granite, from the Georgia Quincy Granite Company's quarry, near Sparta, Hancock county.
XXV Porphyritic granite, from near Line creek, Fayette county.
XXVI Porphyritic granite, from Flat-rock, Pike county.
XXVII Porphyritic granite, from the Heggie rock, Columbia county.
XXVIII Porphyritic granite, from the Sparta quarry, Hancock county.
XXIX Porphyritic granite, from near Milledgeville, Baldwin county.
XXX Porphyritic granite, from the Moseley quarry, near East Point, Fulton county.
XXXI Porphyritic granite, from 10 miles South of Greensboro, Greene county.
XXXII Porphyritic granite, from the Charley Rocker quarry, Hancock county.
XXXIII Foliated porphyritic granite (granite-gneiss), from the Brinkley Place, Warren county.
XXXIV Porphyritic granite, from the McCollum quarry, near Coweta, Coweta county.
XXXV Contorted biotite granite-gneiss, from the Odessa quarry, Meriwether county.
XXXVI Contorted biotite granite-gneiss, from the Crossley quarry, near Lithonia, DeKalb county.
XXXVII Contorted biotite granite-gneiss, from the Snell quarry, Snellville, Gwinnett county.
XXXVIII Contorted biotite granite-gneiss, from the Tilley quarry, Rockdale county.
XXXIX Contorted biotite granite-gneiss, from Arabia mountain, near Lithonia, DeKalb county.
XL Foliated biotite granite, from Flat-rock, near Franklin, Heard county.
XLI Foliated biotite granite, from Flat Shoals, Meriwether county.
XLII Foliated biotite granite, from Flat-rock, Coweta county.
XLIII Contorted biotite granite-gneiss, from the Southern Granite Company's quarry, near Lithonia, DeKalb county.
XLIV Biotite granite-gneiss, from the Freeman quarry, near Covington, Newton county.
XLV Biotite granite-gneiss, from Athens, Clarke county.
XLVI Biotite granite-gneiss, from McElvaney Shoals, Gwinnett county.

MOLECULAR RATIOS OF THE OXIDES OF THE GEORGIA GRANITES

	I	II	III	IV	V	VI	VII	VIII
SiO_2	1.209	1.183	1.173	1.171	1.169	1.167	1.164	1.164
Al_2O_3	.145	.160	.161	.158	.169	.153	.160	.163
Fe_2O_3	.005	.007	.007	.007	.007	.008	.012	.009
CaO	.021	.032	.030	.046	.036	.043	.032	.034
MgO	.005	.008	.007	.007	.013	.013	.009	.009
Na_2O	.079	.077	.080	.078	.070	.080	.071	.078
K_2O	.056	.049	.059	.051	.050	.057	.059	.056
Na_2O + K_2O	.135	.126	.139	.129	.120	.137	.130	.134

	IX	X	XI	XII	XIII	XIV	XV	XVI
SiO_2	1.160	1.159	1.158	1.157	1.156	1.155	1.154	1.151
Al_2O_3	.168	.163	.161	.156	.168	.166	.157	.173
Fe_2O_3	.008	.006	.007	.008	.008	.010	.010	.008
CaO	.038	.030	.037	.034	.038	.049	.033	.058
MgO	.016	.006	.021	.013	.014	.015	.007	.013
Na_2O	.073	.094	.080	.069	.083	.075	.072	.073
K_2O	.052	.041	.052	.054	.048	.048	.052	.035
Na_2O K_2O	.125	.135	.132	.123	.131	.123	.124	.108

	XVII	XVIII	XIX	XX	XXI	XXII	XXIII
SiO_2	1.151	1.146	1.146	1.146	1.139	1.115	1.054
Al_2O_3	.162	.173	.161	.164	.174	.178	.195
Fe_2O_3	.008	.007	.006	.006	.007	.019	.017
CaO	.032	.038	.031	.048	.050	.088	.051
MgO	.019	.012	.032	.025	.017	.031	.012
Na_2O	.075	.080	.076	.077	.070	.061	.066
K_2O	.053	.041	.062	.039	.037	.021	.051
Na_2O K_2O	.128	.121	.138	.116	.107	.082	.117

MOLECULAR RATIOS OF THE OXIDES OF THE GEORGIA PORPHYRITIC GRANITES

	XXIV	XXV	XXVI	XXVII	XXVIII	XXIX
SiO_2	1.181	1.181	1.170	1.162	1.158	1.156
Al_2O_3	.155	.155	.164	.167	.163	.166
Fe_2O_3	.008	.011	.009	.010	.011	.012
CaO	.038	.032	.035	.039	.041	.036
MgO	.001	.023	.019	.024	.007	.021
Na_2O	.081	.063	.059	.064	.076	.055
K_2O	.049	.049	.053	.043	.047	.048
Na_2O K_2O	.130	.112	.112	.107	.123	.103

	XXX	XXXI	XXXII	XXXIII	XXXIV
SiO_2	1.152	1.152	1.127	1.105	1.060
Al_2O_3	.163	.168	.159	.179	.200
Fe_2O_3	.007	.009	.014	.015	.013
CaO	.036	.033	.042	.052	.060
MgO	.015	.019	.019	.030	.037
Na_2O	.078	.065	.090	.059	.076
K_2O	.047	.058	.048	.043	.048
Na_2O K_2O	.125	.123	.138	.102	.124

MOLECULAR RATIOS OF THE OXIDES OF THE GEORGIA GRANITE-GNEISSES

	XXXV	XXXVI	XXXVII	XXXVIII	XXXIX	XL
SiO_2	1.272	1.266	1.264	1.257	1.252	1.249
Al_2O_3	.130	.128	.137	.134	.134	.134
Fe_2O_3	.007	.005	.004	.005	.005	.005
CaO	.020	.018	.012	.016	.016	.018
MgO	.002	.006	.003	.004	.004	.006
Na_2O	.064	.062	.058	.062	.060	.075
K_2O	.039	.049	.059	.045	.053	.050
Na_2O K_2O	.103	.111	.117	.107	.113	.125

	XLI	XLII	XLIII	XLIV	XLV	XLVI
SiO_2	1.246	1.232	1.216	1.186	1.158	1.149
Al_2O_3	.151	.139	.144	.151	.166	.161
Fe_2O_3	.006	.008	.008	.007	.014	.014
CaO	.014	.019	.022	.024	.032	.029
MgO	.002	.005	.001	.008	.032	.010
Na_2O	.077	.074	.067	.080	.061	.070
K_2O	.050	.026	.056	.056	.036	.044
Na_2O } K_2O }	.127	.100	.123	.136	.097	.114

A close examination of the molecular ratios of the oxides given in the foregoing tables, as calculated from the analyses, shows a tendency in the alumina, iron and lime contents to gradually increase as the silica decreases for the three rock-types. This condition is apparently more strikingly shown, in the case of the porphyritic granites, than in the normal granites and granite-gneisses. The gradual rise in alumina, with decreasing silica, is well illustrated, in the case of the granite-gneisses.

The tables of molecular proportions further show, that the alkalies, in sum total, remain fairly constant, with but slight variation.

These statements would seem to indicate, that no fixed relation exists between the alumina, silica and alkalies, since the tendency is for the alumina to increase as the silica decreases, while the alkalies remain approximately the same.

THE OXIDE RATIOS OF THE GEORGIA GRANITES

$\frac{Na_2O}{K_2O}$ ratio —

X 1:2.29	XVI 1:2.08	XVIII 1:1.95	XXI 1:1.89	XIII 1:1.72	II 1:1.57
XIV 1:1.56	XI 1:1.53	IV 1:1.52	I 1:1.41	XVII 1:1.41	V 1:1.40
VI 1:1.40	IX 1:1.40	VIII 1:1.39	XV 1:1.38	III 1:1.35	XXIII 1:1.29
	XII 1:1.27	XIX 1:1.22	VII 1:1.20	XX 1:0.86	

$\frac{Na_2O + K_2O}{SiO_2}$ ratio —

XVI 1:10.65	XXI 1:10.64	XX 1:10.41	V 1:9.74	XVIII 1:9.47	XII 1:9.40
XIV 1:9.39	II 1:9.38	XV 1:9.30	IX 1:9.28	IV 1:9.08	XXIII 1:9.00
XVII 1:8.99	I 1:8.96	VII 1:8.95	XIII 1:8.82	XI 1:8.77	VIII 1:8.68
	X 1:8.58	VI 1:8.51	III 1:8.43	XIX 1:8.30	

$\frac{Al_2O_3 + Fe_2O_3}{SiO_2}$ ratio —

I	VI	IV	II	XII	III
1:8.06	1:7.24	1:7.09	1:7.08	1:7.05	1:6.98
XV	XI	XIX	X	XVII	VII
1:6.91	1:6.89	1:6.86	1:6.85	1:6.77	1:6.76
VIII	XX	V	IX	XIII	XIV
1:6.76	1:6.74	1:6.64	1:6.59	1:6.56	1:6.56
XVIII	XVI	XXI	XXIII		
1:6.36	1:6.35	1:6.29	1:4.97		

$\frac{CaO + MgO}{SiO_2}$ ratio —

I	X	III	II	XV	VII
1:46.50	1:32.19	1:31.70	1:29.57	1:28.85	1:28.39
VIII	XII	V	XVIII	XVII	XIII
1:27.06	1:24.61	1:23.85	1:22.92	1:22.56	1:22.22
IV	IX	VI	XI	XIX	XIV
1:22.09	1:21.46	1:20.83	1:19.96	1:18.19	1:18.04
XXI	XXIII	XVI	XX		
1:17.00	1:16.70	1:16.21	1:1.569		

THE OXIDE RATIOS OF THE GEORGIA PORPHYRITIC GRANITES

$\frac{Na_2O}{K_2O}$ ratio —

XXXII	XXIV	XXVIII	XXXIV	XXVII	XXXII
1:2.08	1:1.65	1:1.60	1:1.58	1:1.48	1:1.39
XXV	XXIX	XXX	XXXI	XXVI	
1:1.28	1:1.14	1:1.12	1:1.12	1:1.11	

$\frac{Na_2O + K_2O}{SiO_2}$ ratio —

XXIX	XXVIII	XXXIII	XXV	XXVII
1:11.22	1:10.85	1:10.83	1:10.54	1:10.44
XXVIII	XXXI	XXX	XXIV	XXXIV
1:9.41	1:9.36	1:9.21	1:9.08	1:8.54
XXXII				
1:8.16				

$\frac{Al_2O_3 + Fe_2O_3}{SiO_2}$ ratio —

XXIV	XXV	XXX	XXVI	XXVIII	XXXII
1:7.24	1:7.11	1:6.77	1:6.76	1:6.65	1:6.51
XXXI	XXIX	XXVII	XXXIII	XXXIV	
1:6.50	1:6.49	1:6.24	1:5.69	1:4.97	

$\frac{CaO + MgO}{SiO_2}$ ratio —

XXIV	XXVIII	XXX	XXXI	XXVI
1:30.28	1:24.12	1:22.58	1:22.15	1:21.66
XXV	XXIX	XXXII	XXVII	XXXIII
1:21.47	1:20.28	1:18.47	1:18.44	1:13.47
XXXIV				
1:10.92				

THE OXIDE RATIOS OF THE GEORGIA GRANITE-GNEISSES

$\frac{Na_2O}{K_2O}$ ratio —

XLI	XLV	XXXV	XLVI	XL	XLIV
1:2.96	1:1.69	1:1.64	1:1.59	1:1.50	1:1.42
XXXVIII	XLIII	XLII	XXXVI	XXXIX	XXXVII
1:1.37	1:1.34	1:1.32	1:1.26	1:1.13	1:0.98

$\frac{Na_2+K_2O}{SiO_2}$ ratio —

XXXV	XLI	XLV	XXXVIII	XXXVI
1:12.35	1:12.09	1:11.93	1:11.74	1:11.40
XXXIX	XXXVII	XLIII	XLVI	XL
1:11.07	1:10.80	1:10.39	1:10.07	1:9.99
	XLII		XLIV	
	1:9.47		1:8.72	

$\frac{Al_2O_3+Fe_2O_3}{SiO_2}$ ratio —

XXXVI	XXXV	XXXVIII	XXXIX	XL	XXXVII
1:9.50	1:9.28	1:9.04	1:9.00	1:8.98	1:8.96
XLII	XLIII	XLI	XLIV	XLV	XLVI
1:8.38	1:8.00	1:7.93	1:7.50	1:6.65	1:6.56

$\frac{CaO+MgO}{SiO_2}$ ratio —

XXXVII	XLI	XXXVIII	XXXIX	XXXV
1:84.26	1:77.91	1:62.85	1:62.60	1:57.80
XLIII	XXXVI	XL	XLII	XLI
1:52.86	1:52.75	1:52.04	1:51.33	1:37.06
	XLVI		XLV	
	1:29.46		1:18.09	

Discussion of the Oxide Ratios

Several oxide ratios of these rocks are considered below, which further serve to illustrate the relationship existing between the three rock-types, as distinguished above.

The $\frac{Na_2O}{K_2O}$ *ratio.*—Out of forty-five computed oxide ratios, the Na_2O to K_2O ratio is found to be constantly greater than unity. There are several cases, however, in which the ratio very closely approaches unity. The most striking feature noticed is the exact or close approximation, in the ratio, to a whole number; for example, 1 : 1, 1 : 2 or 1 : 3; while, in the majority of cases, it varies but slightly from some multiple of a fourth; as 1 : 1¾, 1 : 1½, or 1 : 1¼. Practically no variation from these proportions occurs in either one of the rock-types, as distinguished in this report; and, in each type, nearly the same difference exists between the greater and lesser ratios. This apparently leads to the conclusion, that the Na_2O and K_2O show a tendency, in the Georgia granitic rocks, to exist in stoichiometric ratios, with respect to each other.

The $\frac{Na_2O+K_2O}{SiO_2}$ *ratio.*—An examination of this ratio shows practically the same uniformity for the three types; and, in a general way, corresponds closely with the grouping used above.

The $\frac{Al_2O_3+Fe_2O_3}{SiO_2}$ *ratio.*—This ratio emphasizes very strongly the close relationship existing between the SiO_2 and the $Al_2O_3+Fe_2O_3$ contents. It will be

Fig. 1

Fig. 2

BOULDER OUTCROPS OF PORPHYRITIC GRANITE, NEAR EAST POINT, FULTON COUNTY, GEORGIA. FIG. 2 SHOWS A LARGE BOULDER PARTIALLY WORKED UP.

noticed, that the $Al_2O_3 + Fe_2O_3$ increases proportionately as the SiO_2 decreases, for each of the rock-types. The normal granites show the greatest variation between the maximum and minimum ratios.

The same relationship is quite as strongly marked in the $\frac{CaO + MgO}{SiO_2}$ *ratio*, for the three groups.

An examination of the $\frac{Na_2O + K_2O}{Al_2O_3}$ *ratio* indicated the following ratio variations for the normal granites:— 1 : 1 to 1 : 1.5 + ; for the porphyritic granites, 1 : 1.25 to 1 : 1.5 + ; and for the granite-gneisses, 1 : 1.25 to 1 : 1.5 —.

Mineral Constituents

The close similarity in mineral composition, between the three types of granitic rocks here distinguished, cannot be emphasized too strongly. They are as nearly identical in mineral composition, as is possible. The minerals, found in one, are invariably present in the other. Furthermore, the minerals, most abundant in the one, also predominate in the other. It is unnecessary, therefore, to detail separate descriptions of the different minerals occurring in each rock-type; but a general description here follows, with whatever differences existing pointed out.

The granitic rocks of Georgia are composed of the essential minerals, quartz and the potash feldspars, orthoclase and microcline, with biotite as the chief accessory, associated with varying proportions of muscovite, and with plagioclase as accessory feldspar. Besides these, certain other minerals are always present in microscopic proportions, some of which are of secondary origin. Enumerated as nearly as possible in the order of their relative abundance, the minerals are: Orthoclase, quartz, microcline, plagioclase, biotite, chlorite, muscovite, epidote, apatite, zircon, iron-oxide, pyrite.

A number of other minerals occur sporadically in several localities, such as calcite, garnet, tourmaline, hornblende, hyalite, molybdenite and uranophane, which deserve local description.

Orthoclase.— With few exceptions, orthoclase is the most abundant mineral in the granitic rocks of the State. Numerous thin sections were studied, however, in which microcline was present in equal proportions with the orthoclase; and in several cases, it was the predominating feldspar species in the rock. In crystal outline, the orthoclase varies from perfect, idiomorphic crystals in the phenocrysts of some of the porphyritic granites, through hypidiomorphic forms (prismatic habit) in the Oglesby blue granite area, to truly allotriomorphic individuals in the granites and granite-gneisses and the ground-mass of the porphyritic granites. The individuals vary in size from less than one millimeter in the fine-grained granites, to more than fifty millimeters (two inches) long in the phenocrysts of the porphyritic granites. The best examples of the large phenocrysts are found at the following localities: The Heggie-rock, three miles east of Appling, Columbia county; Flat-rock, ten miles south of Greensboro, Greene county; Cedar-rock, nine miles west of Zebulon, Pike county; The Georgia Quincy Granite Company's quarries, near Sparta, Hancock county; near Line creek, Fayette county; McCollum's place, near Coweta station, Coweta county; near Palmetto, Campbell county; and near East Point, Fulton county.

Chemical analyses made of the feldspar phenocrysts in two of the porphyritic granites occurring in Columbia and Coweta counties, show that, in each case, approximately one-third of the potassium, in the straight potassium ortho-silicate molecule, is replaced by sodium.[1] With the exception of the phenocrysts in the porphyritic facies of the granites, and the hypidiomorphic tendency in some of the areas, the orthoclase is prevailingly allotriomorphic in crystal outline.

The orthoclase individuals are usually opaque, with a dull white, or at times, slightly pinkish tint. When viewed in parallel polarized light, it has a characteristic blue-gray tint. The usual cleavage planes, parallel to the base (001) and the clinopinacoid (010), are well marked. Twins according to the Carlsbad law are very common, both in the porphyritically developed and the granitic orthoclase. The large Carlsbad phenocrysts in the porphyritic rock facies, and the much smaller twinned crystals in some of the even-grained granites are very characteristic, macroscopically. One of the most distinctive features of a part of the orthoclase is the somewhat abundant spindle-shaped intergrowths of orthoclase and albite as microperthite, characteristic of all the granitic rocks, thus far studied. In many cases, the albite lamellæ do not run completely through the crystal as in plagioclase; but they appear as irregular, wedge-shaped bands and broad stringers, which, at times, narrow to a point after passing partially through the crystal. In most cases, however, the lamellæ are nearly continuous through the crystal; but they are extremely irregular in outline, and in this way, differ markedly from the straight, parallel bars of the plagioclase twinning. This structure is entirely microscopic, and is never apparent to the unaided eye. It is, therefore, microperthitic. As a rule,

[1] See pages 92 and 235.

the crystals do not appear to be single individuals; but they are more frequently interlain with the albitic stringers and spindles.

The larger individuals of orthoclase, as well as those of the other feldspar species, present in the Georgia rocks, contain inclusions of apatite and zircon, and droplike inclusions of quartz and of other feldspar species. Inclusions of all the ground-mass minerals occur in the orthoclase phenocrysts, seen in the porphyritic facies of the granites. In these, the biotite inclusions are very abundant, and usually large, always rendering them readily identifiable by the unaided eye. These included grains extinguish at different times under crossed nicols, with reference to each other and the host, and are not arranged, as a rule, with any regularity or along any definite lines. With few exceptions, the grouping is, on the contrary, very irregular, and entirely without regard to optical orientation. Zonal structure is frequently very plain; but the variation in extinction between center and periphery is not great.

The specimens of rock, collected from the area studied, were generally comparatively fresh, and the feldspars rarely indicated more than an incipient stage of alteration. The porphyritic granites offer many exceptions to this, however, owing to the fact, that there were but few quarries opened in this class of rock; and hence, the feldspar constituent is frequently badly altered. When possible, the samples were always taken from the quarries, where good material could generally be obtained; and, in such, the feldspars were usually in a well preserved and fresh condition. In thin sections of the rock, representing an advanced stage in feldspathic decomposition, the individual is almost completely clouded and opaque, with the usual decomposition products formed; muscovite, in minute and brilliant double-refracting scales, and kaolin, with, usually, some epidote; and, in cases, where a migration of solutions from the adjoining ferro-magnesian mineral, biotite, has taken place, chlorite is a constant constituent.

MICROCLINE.—In the rocks of many of the localities studied, the microcline is equal to, and occasionally exceeds in amount the orthoclase present. In nearly every case, it constitutes one of the essential, and therefore, most important minerals in the rocks, as regards amount and occurrence. It is characteristically developed, and is present in about equal amounts in each of the three granitic rock-types. The only apparent difference, between the microcline and the orthoclase, is the gridiron or cross-hatched structure of the former, seen under crossed nicols. Like orthoclase, the microcline varies greatly in size and form; since it is an important constituent of each group, and usually occurs both porphyritically developed (phenocrysts), and as a constituent in the ground-mass of the porphyritic facies. The porphyritic individuals may occur in allotriomorphic form; but usually they have idiomorphic outlines, with distinct prismatic habit, elongated parallel to the clino-axis. As a ground-mass constituent, it also shows considerable variation in size. The larger individuals manifest a slight tendency, in most cases, to rudely prismatic or tabular habit; but, in no case, were any crystal faces observed. It is, therefore, strikingly similar to the orthoclase in form and habit, and is without crystal outline, occurring only as irregular outlined grains, or anhedra, except when porphyritically developed. In some cases, notably the Palmetto–Line Creek–Coweta porphyritic area, the outline of the feldspar phenocrysts is jagged and uneven, in consequence of the merging of the feldspar porphyritic mineral into that of the ground-mass. Sometimes, several feldspar phenocrysts occur, grown in juxtaposition, without any definite relation between their orientations, apparent. Frequently, the microcline, like the orthoclase, shows lenses or stringers of a plagioclase (albite) inmicroperthitic intergrowth. Cleavage planes in one direction are clearly visible. The larger microcline individuals are invariably characterized by abundant inclusions of irregularly outlined grains of quartz and other ground-mass minerals; and primary inclusions of prismatic crystals of apatite and zircon, without trace of orientation. This ragged outline is even more strikingly shown, in the microcline of the contorted granite-gneisses, than in that of the porphyritic and non-porphyritic granite facies. In general habit, the two potash feldspars, orthoclase and microcline, are very similar, for the three rock-types, in which they occur associated. It frequently happens, that in the thin sections of the rock showing the greatest amount of mechanical strain, the gridiron structure has been greatly distorted; and the twinning lines crossed at oblique angles instead of making angles of 90 degrees.

The great abundance of the grating-structured feldspar in all the Georgia granitic rocks, strongly suggests, since they have been subjected to profound and intense dynamo-metamorphism, due to orographic movements, that the microcline structure may have been, in part, secondarily imparted. Some of the microcline is indubitably primary; while the origin of a considerable portion is still in doubt.

PLAGIOCLASE. — The large percentage of soda and the correspondingly low percentage of lime, characterizing these rocks, as shown by the chemical analyses, make it certain, that the plagioclase consists of albite and oligoclase. The optical behavior, also, generally indicates, that both albite and oligoclase are present. Plagioclase is present, to some degree, in every thin section of the rocks examined. Single individuals are only sparingly present in some of the sections; but the albite stringers, intergrown with the potash feldspars as microperthite, are somewhat more abundant. As single individuals, the plagioclase is readily distinguished from the other feldspathic constituents by the polysynthetically twinned lamellæ, after the albite law. The plagioclase is, in contrast with the potash feldspars, orthoclase and microcline, more or less idiomorphic in outline, exhibiting short prismatic or lath-like forms, without well defined crystal faces. The double-refraction is somewhat stronger, and zonal structure, more frequent, than in the potash feldspars. The prevailingly low extinction angles, rarely exceeding ten degrees, measured with the twinning bars, indicate plagioclase, of very acid character.

The final products of decomposition of the plagioclase are much the same as those from orthoclase and microcline, described under the former. Usually, a somewhat more advanced stage of decay is shown in the plagioclase than in the potash feldspars, of most of the thin sections studied, indicating greater susceptibility to decomposition.

QUARTZ. — The quartz, occurring in the granitic rocks of the State, is of the ordinary kind, as regards both occurrence and relative abundance, as for similar rocks elsewhere, characterized by the same degree of acidity. This being the last mineral to consolidate (crystallize) from the magma, it forms very irregular grains (anhedra), of varying size, with the outlines determined by the older constituents. These grains are, therefore, allotriomorphic. There are very strong indications, however, that the consolidation of the orthoclase, microcline and quartz went on in part, simultaneously. The quartz is also very common, as drop-like inclusions in the larger feldspar individuals. Not the slightest tendency toward idiomorphic outline was observed in any of the quartz individuals present. It varies from perfectly clear and transparent anhedra to the ordinary dark and smoky variety. It always appears fresh, being of course, very much more stable under atmospheric conditions, than any of the other constituents. This mineral, under the microscope, is invariably characterized by marked undulous extinction, and is crossed by innumerable lines of fracture. The same cataclastic phenomena are frequently manifested in the individuals of the feldspathic constituent. In many cases, the fracture lines have been subsequently filled with mineral matter, of a high double-refracting nature, not definitely indentified. Fluid and gas inclusions are common, as is usual in the quartz of granites. Exceedingly fine and greatly drawn out threads of rutile, probably, occasionally occur; as do frequently foils of biotite. The slender threads of supposed rutile are too fine to admit of specific determination. There is usually some apatite, in the form of slender prisms, and small colorless crystals of zircon, recognizable, in the latter case, by their strong double-refraction.

In thin sections, the quartz is seen to occur, either as primary individual anhedra, as described above, or as intergrowths with the feldspar, forming the so-called micropegmatitic structure. This structure was well developed in nearly every section of the rocks studied. The quartz-feldspar intergrowths usually occur as rounded areas or discs, occasionally showing irregular outlines, such as result from magmatic resorption. It frequently happens, that the quartz and feldspar intergrowths are enclosed by larger individuals of feldspar. They are very often formed at and near the contact between the larger quartz and feldspar grains, which further proves the contemporaneity of these minerals in crystallization. Everything points to the conclusion, that this structure is a product of primary crystallization from the molten granite magma.

BIOTITE. — This mineral is universally present in the Georgia granites; and, in every instance save one, it occurs as the characterizing accessory. Hence, the rocks are biotite granites (*granitites*) and gneisses. It occurs, either as closely grouped, aggregated plates and foils, or in single, individual shreds, of various sizes. It is usually distributed quite uniformly through the granites, imparting an even gray tone to the rock; while, in the gneisses, it occurs orientated along definitely parallel lines, from dynamometamorphism, in the direction of the longer diameters, imparting a distinctly laminated or foliated structure. It invariably occurs elongated in the direction parallel with the cleavage, so as to form somewhat long narrow plates.

In the fresh plates, the cleavage parallel to the base (001) is perfect; but, in most cases, where decomposition has advanced, the folia have lost their cleavage and elasticity and have become brittle. Inclusions are rather abundant in some of the foils; but, as a rule, they are absent. The axial angle is very small, and the extinction is at right-angles, and parallel with the cleavage planes. It varies in color, from a light to a deep brown, and has metallic lustre and strong pleochroism. The absorption is very marked, for the ray vibrating parallel to the basal cleavage, (001), and is less strong for the ray vibrating at right-angles with the plane of cleavage. The absorption is : —

Light to deep yellowish brown
Dark-green to opaque

This mineral is especially distinguished by its strong absorption and perfect cleavage parallel with the base. In many cases, it is intergrown with thin plates and foils of a colorless muscovite, which have barely noticeable pleochroism, but high double-refraction ; and, in such cases, it is undoubtedly a primary constituent. As a rule, the biotite plates are much stouter, and are generally larger, for the porphyritic, than for the normal granites and gneisses.

Alteration and decay (the results principally of weathering) have progressed quite markedly in this constituent. The minerals, resulting from the alteration and decomposition of the biotite, are prevailingly a green to red-colored, opaque chlorite, with slight pleochroism and weak double-refraction; and a yellowish brown, pleochroic and strong double-refracting epidote. In the most advanced stage of decay, more or less ferrite is liberated, which discolors the surrounding areas. The first indication of alteration is a change in color of the biotite to green, along the cleavage planes and peripheries, without apparent change in optical properties. Many cases were observed, of the brown-colored foils of biotite, in which green chloritic lamellæ were intercalated, indicating the manner, in which a pseudomorph of chlorite after biotite may take place. Following this change, is the loss of elasticity of the folia and the assumption of brittleness, accompanied by a rapid decrease in double-refraction ; the loss of cleavage, and a structureless, opaque mass resulting ; and finally, a breaking up process, ending in the formation of the usual products, chlorite, epidote and ferrite. The process consists, therefore, in a change of color and a loss of elasticity and cleavage, but with strong absorption and double-refraction ; and it results in the formation of a brittle, non-cleavable, green to reddish-brown, opaque product, with faint pleochroism and very weak double-refraction — chlorite. In many cases, the process has advanced further, and the biotite is completely altered to a somewhat idiomorphic epidote, with, in several instances, well marked cleavage. This is especially noticeable in the fine and even textured granite from the Cole quarry, near Newnan, Coweta county ; and in a more basic and somewhat coarser-grained granite occurring near Grantville, in the same county.

MUSCOVITE. — Muscovite occurs, both as a primary and a secondary mineral, in nearly all the Georgia granites studied. In quantity, it is quite variable, from place to place. As a secondary product, the freshness of the rock controls the amount present. It is mostly absent as a secondary mineral, from thin sections of the freshest rock. It results, as a direct product, from the alteration of the feldspars, with which it is necessarily associated as a derived mineral.

Variation in form, from large, irregularly shaped shreds and plates, to small, thin scales, scattered irregularly through the feldspars, are observed, with brilliant colors, when examined between crossed nicols. The feldspar individuals, from which the muscovite is derived, are more or less decomposed, and are usually filled with kaolin and other ordinary products of feldspathic decay.

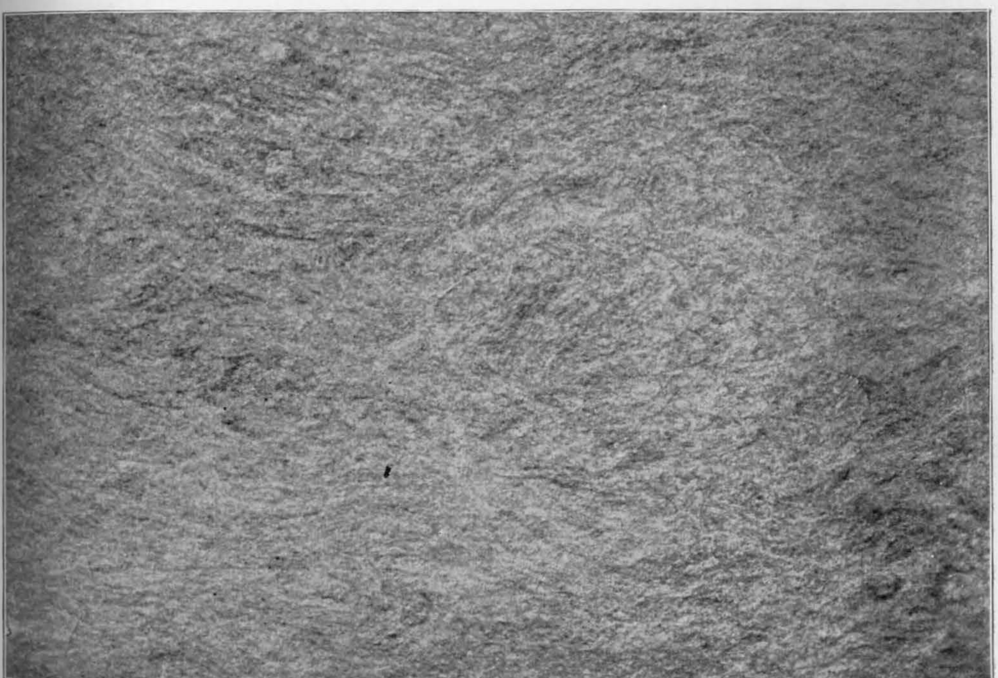
As a primary or original constituent, it becomes the characterizing accessory in the rock at several localities, the principal one of which may be mentioned—the famous Stone Mountain granite, a biotite-bearing muscovite granite. In a number of localities over the State, muscovite occurs in amounts, sufficient, almost, to justify the name muscovite-biotite granite. From this amount, it varies, to only one or two single small filaments, intergrown with the biotite. As an original constituent, it varies in form, from large, stout, irregularly bounded plates and foils, single and grouped, to long and slender single filaments. It has a high index of refraction and strong double-refraction; is colorless, with faint yellowish absorption for the ray vibrating parallel to the cleavage; and it invariably occurs intimately associated with the biotite, and often intergrown with it. Frequently, the long foils of the two micas alternate, and have the same optical orientation; while they very often occur without orientation, but apparently penetrating and, in some cases, cutting across each other at various angles. The muscovite is generally free from inclusions and very fresh in appearance; and it is not susceptible, to any great extent, to the action of the atmosphere.

Muscovite, as an original constituent in granites, has been questioned by many. Keyes[1] has, however, clearly shown the occurrence of this mineral to be, in some cases, a primary component in some of the Maryland granites. From Dr. Keyes' description, the occurrence of muscovite in the Maryland rocks is much the same as that in many of the Georgia granites. As described above, the muscovite in the Georgia granites occurs intimately associated with the biotite, frequently as parallel growths,

[1] 15th Annual Report, U. S. G. S., 1893-94, pp. 703-704.

Fig. 1

Fig. 2



SLABS OF CONTORTED GRANITE-GNEISS FROM LITHONIA, GEORGIA.

the relation of the two minerals, leaving but little doubt of their having crystallized contemporaneously. The form and structure, of the muscovite associated with the biotite, is wholly different from that found in association with the partially altered feldspars. In the latter case, the muscovite results as a direct product from the feldspathic decomposition.

The surfaces of many of the joint-planes, cutting the Stone Mountain granite, are coated with a thin veneering of yellowish-green damourite, a variety of muscovite. The damourite is, at times, highly polished and striated; and it has probably resulted from the alteration of certain constituents in the granite, through pressure-metamorphism in the granite-mass, forming the present slicken-sided surfaces. A similar occurrence of damourite has been observed in some of the other larger granite-masses in other parts of the State.

CHLORITE.—This mineral is generally present, in varying quantities, in all the granitic rocks of the State, as a derived or alteration product. It results directly from the alteration of the biotite; although it is not entirely confined to the biotite areas; for it happens, that, in many cases, solutions from the biotite have been carried over to the adjoining feldspar individuals, where chlorite is frequently formed, with other secondary minerals, from feldspathic decomposition. The greater part of it, however, occupies the original biotite areas. The first change observed consists apparently in the production of a green color along the cleavage lines and peripheries of the plates, without materially affecting any of the optical properties; but it is accompanied by a loss of elasticity of the mica folia. Next, follows a fraying-out of the biotite shreds, when the lamellar structure is replaced by a somewhat scaly, fibrous one, and a generally dark, cloudy appearance is taken on. These two stages in the alteration are accompanied by a decided decrease in the strong double-refraction of the biotite. Finally, the entire original crystalline structure is replaced by an opaque, almost amorphous mass, with very weak pleochroism and double-refraction. In the case of the Georgia rocks, this alteration product varies from light-green through dark-green and brown to nearly black, in color. It is accompanied, in most cases, by deposits of brownish, pleochroic and strong double-refracting epidote grains, of varying size and shape. Chloritization is apparently the first alteration or change to take place in the Georgia granites.

EPIDOTE.— Epidote forms an almost constant element in the Georgia rocks, resulting from the alteration of the biotite. It is frequently observed as an accompanying product of feldspathic decomposition, particularly in those cases, where solutions from the biotite are carried over to the adjacent feldspars. Grains of this mineral often occur along the contact of the biotite and feldspar individuals, having been derived from the mutual interaction of these two minerals during the process of weathering.

It occurs as single and aggregated grains, without definite crystal boundaries. The grains vary in size, from very minute particles to large, irregular, thick plates. The granites occurring near Newnan and Grantville, in Coweta county, contain large and somewhat idiomorphic crystals of epidote, which exhibit, in thin section, perfect cleavage, parallel to (001), and a much less distinct cleavage, parallel to (100), in sections parallel to (010). The change from biotite to epidote, in the granites from the above localities, is well marked, and some of the larger grains of epidote contain centres of the partially altered and frayed-out biotite. It varies from colorless to a slightly yellowish brown; it is appreciably pleochroic; and the index of refraction and the double-refraction are considerable.

IRON-OXIDE. — Iron-oxide, usually as very minute grains, is sparingly present in many of the granites. It occurs very limited in amount, except in some of the contorted granite-gneisses, and attracts but little attention. The chemical analyses of the Georgia rocks indicate a low percentage of iron, which is derived almost exclusively from the biotite present. Magnetite is quite abundant, as large macroscopic grains in the contorted granite-gneisses of DeKalb, Gwinnett, Meriwether, Rockdale and Troup counties. In these cases, it exhibits conchoidal fracture and a shiny, metallic lustre, and is black in color. Thin sections of the weathered rock, studied, show no trace of leucoxene. This would suggest the absence of titaniferous iron-oxide. Crystal outline is frequently indicated, though the forms are usually allotriomorphic. In the greatly decomposed specimens of the rock, ferrite very generally occurs as a yellowish-brown stain, derived from the decay of the iron-bearing minerals present, and is usually found uniformly coloring the rock. The soils derived from these granites always show considerable quantities of very small, fairly fresh grains of magnetite, on passing the magnet through the mass.

APATITE. — Apatite is very generally present in the form of short, stout crystals and long, slender, prismatic needles penetrating the essential minerals of the rock, indicating that it crystallized first. As a rule, it occurs in greater abundance in the feldspars, than in the quartz and is almost wholly absent, as inclusions in the biotite. There are many exceptions to this, however, where thin sections of the rock from some localities indicate, that inclusions of this mineral are much more abundant in the quartz than in the feldspar. The crystals are broken only occasionally, and when so, the different parts have, with several exceptions, suffered no movement. The most noteworthy exception is the Constitution granite in DeKalb county, where the inclusions of apatite are well developed in the quartz granules and are frequently curved, bent and broken, with the parts more or less widely separated. It is colorless; but it is readily distinguished from similar inclusions by its index of refraction and weak negative double-refraction. The needles penetrate the host in every direction; and, in some of the feldspar individuals, they occur numerously bunched.

ZIRCON.—Minute zircon crystals occur in the form of rounded stout prisms, generally embedded in the larger minerals, feldspar and quartz, and less frequently, in the biotite. It is much less abundant than the apatite, and has, in many cases, the habit of forming, around the edges of the biotite folia, sometimes partially touching them, as though it had been attracted in some way. Having a high index of refraction and strong double-refraction, and being present as minute crystals, it is very brilliant between crossed nicols, and exhibits strongly marked outlines. These render it readily distinguishable from other microscopic accessories present.

PYRITE.—This mineral is absent in microscopic thin sections of the Georgia granites. In some localities, however, an examination of the quarry faces sometimes discloses the presence of a few scattered grains of pyrite, of variable size and form. It can be stated, however, that, as a rule, the Georgia granites are exceptionally free from this deleterious accessory, which frequently, on account of its rather abundant distribution, proves a source of discoloration to many granites from other localities, when exposed to the atmosphere.

GARNET.—Excepting in the granite-gneisses, garnet is seldom met with, in the granitic rocks of the State. In only one or two cases, has this mineral been observed in thin sections of the true granites. In the Lithonia and Meriwether County belts of highly contorted granite-gneiss, garnet is very abundant, frequently occurring in broad, lenticular bands, or layers, of the rock, of considerable length and decidedly pink in color. At other times, it is more or less evenly distributed through the rock, frequently imparting a decidedly pinkish tint to the gneiss. It is unquestionably a product of dynamo-metamorphism. In thin sections of the rock, it presents a great variety of forms, ranging from well rounded, allotriomorphic grains to idiomorphic crystals with definite crystal boundaries. The individuals are usually small in size; and, in polarized light, they have a slightly pinkish tint.

HORNBLENDE. — This mineral is entirely unknown in the true granites of Georgia and their porphyritic facies. It is a common constituent in a class of thin-banded, dark-blue basic (hornblende) gneisses occurring somewhat abundantly throughout the Piedmont area. The principal localities are in Meriwether, Troup, Heard and Gwinnett counties. In the gneisses from these localities, the hornblende is an essential mineral, and makes up at least from a half to two-thirds of the mineral composition of the rock. It occurs in the form of allotriomorphic plates elongated in the direction of the prismatic cleavage. A variety of color is shown, from light blue-green through various shades to dark-brown. The absorption is very strong; and, in the best cleavable grains, it is light yellowish-brown for the ray vibrating parallel to the cleavage-plane, and dark greenish-brown for the ray vibrating at right angles to this direction. Extinction angles, measured on the cleavage planes, vary from 10° to 24°. It is considerably altered, for the most part, to a light blue-green, massive or "reedy" form of hornblende, without trace of cleavage.

Hornblende is also common in some of the dark-colored granite-gneisses occurring around Atlanta. A few plates, with strong absorption, have been observed in a grano-diorite found near Grantville in Coweta county, and in the Armour's Mill area of sheared, fine-grained granite in Putnam county.

CALCITE.— This mineral is only sparingly present in some of the decayed granites of the State. It has been found, in small quantities, in several cases, in the badly weathered rock, resulting directly as a secondary mineral from the feldspathic decomposition.

TOURMALINE. — Tourmaline in the Georgia granites has, thus far, been observed in only a few localities. It occurs abundantly, as crystal aggregates in rounded white areas of quartz and feldspar, in the Stone Mountain granite, and less abundantly, but in a similar manner, in the Lithonia belt of contorted granite-gneiss. A few scattered crystals have been observed in the porphyritic area, nine miles west of Zebulon in Pike county. It is a common product in some of the larger and coarser-grained pegmatitic intrusions, or dikes. The most noteworthy locality is near LaGrange in Troup county, where large black crystals of the mineral, measuring several inches in length, and proportionally thick, showing prismatic faces and terminal planes, occur with coarsely crystallized pink orthoclase and quartz.

These tourmaline crystals are usually of long habit, measuring from a fraction of an inch to several inches, and are commonly grouped as aggregates. The prismatic faces are nearly always well developed; though, as usual, they are somewhat rounded, and marked by abundant parallel striæ. In some cases, terminal planes also occur. Frequently, the crystals have been badly fractured. The color is always black, in ordinary light.

URANOPHANE.[1] — Uranophane has been observed in only one locality. It occurs as a lemon- to sulphur-yellow coating, or incrustation, in association with hyalite, along the faces of some of the joint-planes in the Stone Mountain granite. Two separately weighed portions of the mineral were carefully freed from impurities, and subjected to chemical analysis by Mr. R. L. Packard, several years ago, in the laboratory of the Geological Survey, yielding the following amounts of uranium oxide: —

	I	II
$U(UO_4)_2$	47.18	61.28

HYALITE. — Like uranophane, hyalite has been noted in only one locality; namely, Stone Mountain. It occurs in intimate association with the uranophane as an incrustation, coating the faces of the joint-planes in the granite.

MOLYBDENITE. — Several irregular masses of molybdenite, measuring less than one inch in diameter, have been observed in the Southern Granite Company's quarry of highly contorted biotite granite-gneiss, located near Lithonia. The occurrence was directly in the hard and firm fresh granite-gneiss, approximately 20 feet from the surface.

CHARACTER OF THE GRANITIC OUTCROPS

As described under individual properties in Chapter III, Part 2, the granitic rocks of the State appear, for the most part, in large, flat, horizontal masses; as dome-shaped areas, of steep and gentle slopes; as large, well rounded boulders scattered over the surface and partially buried in the residual decay; and as ledges exposed along the streams and in ravines. The outcrops of the flat, horizontal masses vary in extent, from one to fifty or more acres; while the dome-shaped areas contain from fifty to many hundred acres of exposed rock. The best illustrations of the former occur in Hancock, Heard, Meriwether and Pike counties.

[1] For further description of this mineral, see pages 115 and 116, and Amer. Jour. Sci., June, 1902, "On the Occurrence of Uranophane in Georgia," by Thomas L. Watson.

Stone Mountain in DeKalb county, which rises to an elevation of 686 feet above the surrounding lowland plane, and which has a basal circumference of approximately seven miles, is the most extensive one of the dome-shaped masses. Pine, Arabia, Collinsville, McDaniel and Rock-Chapel mountains, belonging to the Lithonia belt of contorted granite-gneiss, may be mentioned as examples of some of the other dome-shaped areas, which vary from 75 to 200 feet in elevation. Among similar exposures of the porphyritic granites, occur the Heggie-rock (Cedar-rock) in Columbia county, and the porphyritic area ten miles south of Greensboro in Greene county. Outcrops, illustrating the forms herein described, are frequent throughout the Georgia area.

A scanty granitic soil-covering occurs in places over the larger outcrops. In this, a stunted growth of gnarled cedars, mosses and lichens is usually found. The growth of cedars has become so prevalent over some of the exposures, that the outcrops are referred to, locally, as "cedar-rock." In other cases, a few of the flat horizontal masses are known as "flat-rock," on account of the extent and nature of the outcrop. Cedars, mosses and lichens constitute the bulk of vegetation found covering the rock outcrops.

THE GRANITES AND GRANITE-GNEISSES

The granites and granite-gneisses of the Piedmont region are very closely related, genetically. 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 imparted to them through the action of dynamo-metamorphism. As has been pointed out elsewhere in this report, the granite-gneisses represent unquestionable foliated phases of massive granites, similar to the present areas, but of an earlier period of intrusion.

ROCK TYPES.—Mineralogically, the granites of Georgia are divisible into three leading types: (1) *Biotite granite or granitite*, under which head nearly all the granites of the State may be grouped; (2) *Muscovite-biotite granite;* and (3) *Biotite-bearing muscovite granite*, of which the Stone Mountain granite is the best representative. The texture of granite depends, of course, largely upon the physical conditions, under which the magma solidified. Based on texture, therefore, there are, among the Georgia granitoid rocks, only two well marked facies—*granitic and porphyritic.* The granitic facies includes the vast majority of the acid rocks. The representative texture of this type is even-grained, medium allotriomorphic-granular, without apparent approach to a porphyritic texture. The porphyritic type is represented by large phenocrysts of feldspar, embedded in a coarse-grained, well crystallized ground-mass. This type is merely a local facies of the larger and more extensive granitic type, and its ground-mass is usually somewhat coarser-grained than that of the normal granite. When well developed, the two textural types are sharp and clearly differentiated in the extremes of the same mass; but, in nearly every instance, the gradations from one to the other are clearly visible. In the porphyritic areas, the central part of the stock was developed porphyritically, with gradations into the true granitic texture, shown near the peripheral portions. The best sections are seen in Columbia, Greene, Hancock, Coweta, Fayette, Campbell and Fulton counties. In the Columbia, Greene and Fulton County areas especially, gradation, from the coarse-grained, porphyritic texture at the mass-center into the typical even-grained granite toward the margin of the stock, is easily traceable. In several of the porphyritic areas, the feldspar phenocrysts, from one to two inches in length, are so abundant, that it requires a close examination of the hand specimens to recognize a separate ground-mass in the rock. The feldspar phenocrysts are so variable in size and form, and the ground-mass so coarsely granitic, that it becomes difficult, in many cases, to differentiate the ground-mass feldspars from the porphyritically developed ones.

As pointed out elsewhere in this report, the granite-gneisses differ from the more massive rock phases (granite) simply in the marked banded or foliated structure. These are secondary structures induced by long continued and profound dynamo-metamorphism, acting on an original massive rock, similar, in mineralogical and chemical compositions, to the existing massive granitic areas studied.

Based primarily, therefore, on texture and structure, the granitic rocks of Georgia are divisible into the following types: —

Granular

1. *Muscovite-biotite granite*, composed of quartz, orthoclase and microcline, with plagioclase, muscovite and biotite.
2. *Biotite granite*, or *granitite*, having the same constituents as above, with variable proportions of muscovite present.
3. *Biotite-bearing muscovite granite*, having the same constituents as Nos. 1 and 2, with the minimum amount of biotite. The Stone Mountain granite is typical of this kind.

Porphyritic	4. *Porphyritic granite.*—Mineralogically, the same as the normal biotite granites. Feldspar phenocrysts of orthoclase, frequently showing microperthitic structure, and microcline are the porphyritic species.
Schistose or Banded	5. *Granite-gneiss.*—Mineralogically, the same as the porphyritic and non-porphyritic biotite granites. 6. *Hornblende-gneiss.*—Mineralogically, the same as the biotite granites, with the addition of hornblende, less quartz and feldspar.

Pegmatite occurs somewhat abundantly, in connection with all the largest granite masses, as probable segregation-veins in some cases, and intrusive pegmatites in others. Graphic granite, a product of the intercrystallization of quartz and feldspar, is found in limited occurrence in several localities. No account has been taken of the pegmatitic and graphic granite varieties in the above scheme.

ERUPTIVE ORIGIN OF THE GEORGIA GRANITES

The evidence for the igneous origin of the Georgia granites is similar to that detailed by geologists, for like rocks occurring elsewhere, and is from several different sources, as follows: (1) From field relations; (2) from chemical composition; and (3) from microscopic study.

FIELD RELATIONS OF THE GRANITES

The Piedmont region in Georgia consists chiefly of mica-schists and gneisses, cut in numerous places by diabase, diorite and other basic eruptive rocks. The schists and gneisses are further indiscriminately cut, by large masses of granite. Near many of the larger granite masses, occur somewhat well defined granitic dikes, which would usually be regarded as apophyses from the main body, in case the rock were regarded as eruptive, in origin. These dikes, or apophyses, project outward from the main rock-mass and cut abruptly into the adjacent rocks. Seldom, if ever, is the line of contact between the granite and the contiguous fresh rock exactly sharp and determinable, on account of the extreme depth of superficial, residual decay; although, in several cases, the contact has been observed in the zone of partial decay of the two rock-masses, in which the relations of the granites to the surrounding schists were quite apparent.

The mica-schists form a considerable part of the Piedmont crystalline complex, and are vari-colored, thinly foliated, or laminated, rocks, which vary somewhat in mineral composition, from place to place. They usually carry some feldspar, which is quite variable in quantity, being entirely absent as a constituent, in some places, and becoming the predominating one, in others. Fresh exposures of these rock are very rarely met with, in the Georgia area. While the dikes of basic rock, which are quite abundant in the schists, are seldom found actually cutting the granites; still, the field relations leave scarcely any doubt as to their doing so. The dikes vary from a few inches to a hundred feet and more in width; and some of them have been traced for a distance of several miles. They present the usual characteristics of hard, firm, close-grained diabases and diorites, which vary from gray to almost black in color. The diabases vary in mineral composition, from the ordinary olivine-free to olivine-bearing rocks, and from fine- to coarse-granular in texture. The final product of weathering, of all the basic ferro-magnesian-silicate-bearing eruptives, is a stiff, highly ferruginous, deep-red to yellow clay.

No definitely identified inclusions of irregularly shaped fragments of foreign rocks have been observed, in any of the granitic masses studied; but numerous masses, of an irregular character, occur in many of the granitic areas, the origin of which remains somewhat in doubt. They differ quite strongly, in many respects, from the enclosing granite; and, in many cases, they probably represent inclusions of foreign rock. In many localities, however, basic segregations, of various sizes and shapes, which form so common a feature of slowly solidifying granite magmas in the granitic areas, occur. These are very abundant in the Line Creek porphyritic area of Fayette county, where they vary in size, from six inches to several feet in diameter, and in the Greenville Granite Company's granite, near Greenville, in Meriwether county. They are darker in color than the surrounding granite, and are finer grained and more or less rounded in outline; and they display decided porphyritic tendency, in many cases. Irregular, dark areas, of variable dimensions, composed almost entirely of the black biotite, are common in some of the Lithonia quarries.

In the Stone Mountain granite region, abundant light-colored areas, of a few inches in diameter, occur. These are composed of quartz and feldspar, from which the two micas, muscovite and biotite, have been excluded, and in which are bunched together well formed, prismatic crystals of jet-black tourmaline. The tourmaline crystals vary in size, from very minute individuals to others several inches in length. The usual prismatic crystal faces occur rounded, and striated vertically. The crystals are frequently irregularly grouped and distributed through the white mass of quartz and feldspar; but they commonly form areas of parallel, bunched crystals, sometimes partially radiating from a common center in certain directions, closely resembling fan-shaped, and occasionally arborescent, forms. The tourmaline areas are likewise found in some of the Lithonia quarries of contorted granite-gneiss.

A number of thin sections of the feldspar-quartz areas and their included tourmaline aggregates were examined microscopically. The sections showed a mosaic of interlocking quartz and feldspar, similar in all respects to, and containing the same feldspar species as, the granite. Some small foils of secondary muscovite were seen distributed over the surfaces of some of the feldspar individuals. The tourmaline is closely associated with both the quartz and the feldspar, filling, at times, the interspaces. It is more intimately associated with the feldspar, however; and its distribution through some of the large microcline and oligoclase individuals, as partially connecting irregular and ragged granules, closely resembles the poikilitic structure.

Since segregated areas of biotite are somewhat common in the Stone Mountain granite, and this mineral shows in general a strong tendency to segregate in igneous masses; and since it is invariably absent or excluded from the white quartz-feldspar areas of bunched tourmaline crystals in this rock, it seems difficult to ascribe the tourmaline areas to the usual process of segregation, especially in the presence of considerable biotite. Neither can the tourmaline bunches be ascribed to the usual contact phenomena, since they are thickly distributed through the entire mass of Stone Mountain granite.

The mode of occurrence, and the intimate relationship of the tourmaline to certain other mineral species present, as shown both macroscopically and microscopically, make it reasonably certain, that the tourmaline areas have resulted from fumaroles charged with boric acid, acting on the feldspars and mica.[1]

WEATHERING.—Not only are the three facies of the granite rocks alike in chemical and mineralogical composition and in the occurrence of micropegmatitic intergrowths in each, which is in full accord with similar rocks of igneous origin; but their form

[1] For a more detailed description of the occurrence of the tourmaline aggregates in the Stone Mountain granite, see the paper, "On the Occurrence of Aplite, Pegmatite and Tourmaline Bunches in the Stone Mountain Granite of Georgia," by Thomas L. Watson. Jour. of Geol., 1902, Vol. X, pp. 186–193.

and manner of weathering in the field are those of igneous masses. The more perfectly banded rocks (granite-gneisses) weather in process and topographic outline, closely similar to the massive granites. Wherever difference in topography between the granite-gneisses and the massive granitic forms occurs, as a result from weathering, it can be readily explained on structural grounds. The chemical and physical processes involved in the weathering of these rocks, as described in Chapter V, are the same.

CONTACT PHENOMENA.—These are rarely seen to advantage, on account of lack of exposures of the fresh rock, which is prevailingly covered to an extreme depth with residual decay. The contacts observed, have been in badly decayed rock, exposed mostly in railroad cuts, in which the usual contact phenomena, common to, and produced in, the fresh rock, have been obliterated by extreme weathering. The transformation, however, from fresh to decayed rock, was not sufficiently advanced in all cases, to render the rocks unidentifiable. The best sections invariably showed sharp contacts between the granitic masses and the adjoining thinly foliated mica-schists. Numerous exposures were observed, in which the granite was overlain by the schists; and, while the associated phenomena, which result from the intrusion of a molten magma into an overlying consolidated rock, had been destroyed, if present, in the sections of the weathered materials, the field relationships between the two, left no doubt in the writer's mind, as to the intrusive character of the acid rock, granite, into the mica-schist.

Careful field-study has revealed a large number of sharp and well defined contacts between the decay of the granitic rocks and that of the thinly foliated mica-schists. The principal contacts between the contorted granite-gneisses and the mica-schists are found in DeKalb, Gwinnett and Rockdale counties. In no case, has any apparent gradation from the granitic rocks into the schist been observed in the field investigation; but on the contrary, the two are, at all times, strongly differentiated.

As the granites occur in the midst of profoundly metamorphosed crystalline schists, it would hardly be expected, that any considerable contact metamorphism of the surrounding rocks would occur.

CHEMICAL EVIDENCE

As pointed out by Rosenbusch, Williams and others, sedimentary rocks show a decided contrast with rocks of igneous origin, in the variable character of their bulk (chemical) composition. The chemical composition of sedimentary rocks must, from necessity of origin (mechanical processes), be purely accidental. Dr. Williams says:[1] "If this composition conforms to any well-recognized igneous type, it is probable, that the rock in question was an eruptive; for, although there would be nothing to prevent a sedimentary bed from having this composition, the chances would be greatly against such a result. On the other hand, if a crystalline rock differs very widely from any well-recognized igneous type, we have reason to believe, that it was originally a sedimentary deposit."

Over seventy chemical analyses of specimens of the Georgia granites and gneisses have been made by the writer, the results of which appear in tabular form elsewhere in this volume. These results have been discussed at some length on pages 238 to 249; and they need not be repeated here, except in their direct bearing on the origin of the rocks. After careful examination of the analyses of these rocks, it will be observed, that practically no appreciable variation exists between the three groups of granitic rocks; but that they are remarkably alike throughout, and hence, must be definitely related genetically. An examination of the analyses shows, that, in spite of the marked schistose structure of the gneisses, they are acid granites in composition, not differing materially from other granites, whose igneous origin is well known. On comparing the analyses of these rocks with those of similar rocks known to be of sedimentary origin, wide variation is shown. Every analysis of the Georgia rocks conforms to, and is in close agreement with, that of a well known igneous rock-type, and in-no-wise resembles that of a clastic rock. Further examination and comparison show, that the bulk composition of the Georgia granitic rocks is essentially the same for similar granites, occurring elsewhere, and proved to be of igneous origin.

Microscopic Evidence

As stated by Williams,[2] the mineral composition and structure of crystalline rocks affords a valuable clue, at times, to the materials, from which they have been derived. While metamorphism frequently results in the formation of new minerals and structures, traces of the original material may be somewhat visible through microscopic study. After serious and careful investigation by petrographers, a limited number of certain silicates have been found to be fairly characteristic of various igneous rocks; while others are known to be equally characteristic of metamorphosed sedimenta-

[1] 15h Annual Report, U. S. G. S., 1893-'94, pp. 663-664.

[2] 15th Annual Report, U. S. G. S., 1893-'94, p. 664.

ries ; and certain others still, common to both types. These may, to some degree, be relied upon, as a guide to the origin of the rocks, in which they are found. It frequently happens, therefore, that mineral composition and structure, as well as chemical and other relations, serve in this way as aids in interpreting the origin of certain rocks.

Special emphasis has been laid elsewhere in this report, on the striking identity in the mineral composition of the granites and granite-gneisses, occurring in Georgia. The rocks are essentially identical in this particular. No mineral is found in one, that does not occur in the other ; and furthermore, those minerals, most abundant in the one, predominate in the other. The mineral composition of these rocks is precisely the same, in all particulars, as that of granites of indisputable igneous origin, occurring elsewhere in the United States. Among the list of primary and essential minerals, not a single one, that is not characteristic of an igneous rock, occurs in either of the three rock-types. The rocks are composed of those minerals, which commonly make up the masses of normal eruptive granites. Feldspar, quartz and biotite are the three essential minerals, and are present in the usual proportions, common to such rocks. They are entirely free from such minerals as staurolite, andalusite, cordierite and kyanite, characteristic of some metamorphosed sedimentaries. Garnet is sparingly present in some of the granites, and occurs quite abundantly in a part of the granite-gneisses ; but, in these cases, it is certainly a product of metamorphism, and is as readily produced by such action in igneous as in sedimentary rocks.

Aside from the essential mineral composition of these rocks, other microscopic evidence of their igneous origin occurs. Almost without exception, the thin sections of the rocks, examined, disclose an abundance of micropegmatitic intergrowths of quartz and feldspar, of irregular size and shape, though usually rounded through probable magmatic corrosion, and showing occasional characteristic embayments, so common in such cases. These intergrowths are equally characteristic of the three rock types, with no apparent variation in any particular, in either case. From the character of the ovals of micropegmatitic structure, they are unquestionably primary, and represent simultaneous crystallization of the two minerals. A detailed description of this structure has already been given, and need not be repeated here.

CONCLUSIONS

Concerning the origin of the granites and their banded phases, there can apparently be but little question. They appear like eruptives in the field; the clastic grains, when seen in thin section of the foliated and banded phases (gneisses), are evidently of dynamic origin; all are sharply angular and none have the outline of water-worn grains. The structure of the gneisses studied is very similar to that of like rocks, occurring elsewhere and shown to be metamorphosed eruptives. Therefore, since they conform to the massive type in mineral and chemical composition, there can be no reason for believing them to be anything but altered igneous rocks. No evidence of any kind is at present apparent, to support the belief, that the gneisses here studied, were ever water deposited sediments, subsequently crystallized by metamorphic processes. As to the origin of the massive granites and their porphyritic facies, there can be no doubt; and, since the gneisses conform, with such regularity in mineral and chemical composition, and field evidences as well, to the massive phases of the granites, from which they differ only in structure, they are likewise believed to be eruptive in origin. These have been subjected to more intense metamorphism, and are, in part, of an earlier period of intrusion, than the massive granites.

GENESIS OF A PART OF THE GEORGIA GNEISSES

The gneisses have already been treated of, at some length, in connection with the granites; but a separate résumé of the facts, bearing on their origin, is here considered necessary. A majority of the granitic rocks in the holo-crystalline portion of the Georgia area are composed of gneisses, both light-colored (acid) and dark-colored (basic) rocks. The light-colored, or acid gneisses, resemble very closely the massive granites, in chemical and mineralogical composition; while the dark-colored or basic gneisses usually carry a considerable amount of hornblende in place of biotite as the essential ferro-magnesian silicate, and a preponderance of plagioclase over the potash feldspars. These features of the basic gneisses suggest, that they are the banded equivalents of the eruptive basic rocks, diabase and diorite, from which they have very likely been derived. They assume slightly porphyritic facies in some localities.

The Georgia area has been subjected to profound metamorphic action, inducing a schistose structure in rock-masses, which have manifestly cooled from molten or liquid magmas. In this way, the original structural relations of the rocks have been largely obliterated; and, in many cases, indications of their original character have been almost completely destroyed. For many of the Georgia gneissic areas, laboratory study has furnished the most trustworthy evidence as to origin; and, in every case, it has proved a most valuable clue.

Microscopic study has shown the first evidence of shearing in a normal granite to be an optical disturbance in the quartz and feldspar, known as wavy or undulous extinction. From this, occurs every intermediate phenomenon, associated with mechanical strain, to that of complete shattering of the individual grains, and, in extreme cases, a removal of the parts, in the final stage of the process. These phenomena consist of fracture lines, crossing the crystals in innumerable directions; development of cross-hatching structure in the feldspars, resembling the complex twinning in microcline; and the slipping of the individual crystals past each other, resulting in the rounding of the corners, and the formation of fine-grained, shattered mozaics ("mortar structure") around and between the quartz and feldspar grains.

This, in brief, is what has occurred to the Georgia gneisses, treated of in this report. The Lithonia and Meriwether County areas of contorted biotite gneiss are surprisingly free from clastic structures, such as peripheral shattering and fractures; and the thin sections indicate a typical intricately interlocking granitic texture. During the periods of intense metamorphism, through which these areas have passed, the gneisses have in all probability been recrystallized. Their chemical and mineralogical compositions have been shown to be those of a normal granite. In each case, the chemical analysis closely conforms to that of the massive granite type occurring in the State; and the same minerals, found in one, predominate in the other, with usually the same accessories common to both. For these reasons, the acid gneisses are designated *granite-gneisses*; as they are regarded by the writer to have been derived from original massive granites.

GENESIS OF THE GEORGIA PORPHYRITIC GRANITES[1]

The porphyritic granites are closely allied to the massive granites in chemical and mineral composition. These rocks have received adequate description, in the discussion of the individual properties in Chapter III. Hence, it is only necessary here, to sum up their chief features. The potash feldspars, orthoclase and microcline,

[1] Watson, Thomas L., On the Origin of the Phenocrysts in the Porphyritic Granites of Georgia, Jour. of Geol., 1901, Vol. IX, pp. 97–122.

are the only porphyritically developed minerals in the porphyritic granites. Only the recurrent type of phenocryst is known. They vary from allotriomorphic to flat-tabular, idiomorphic forms, in crystal outline, with the basal and clinopinacoidal cleavages well developed; and they are usually elongated in the clinopinacoidal direction. Generally, the phenocrysts are quite distinct, and can be readily differentiated from the similar ground-mass constituent; although, in several areas, the two seemingly grade into each other. Flow structure was not evident in any one of the areas examined, and resorption, so common to phenocrysts of intratelluric origin, was not apparent in any of the thin sections studied. No orientation was observed among the phenocrysts. They nearly always contain all the ground-mass constituents, which are visible, in most cases, to the unaided eye. The porphyritic texture was apparently developed in the central part of the mass, with the even-granular texture forming the marginal or border portion. The gradation from one rock facies into the other was not clearly defined in all the areas; but it could be easily traced in many.

The absence of (a) definite arrangement, or orientation, among the phenocrysts; (b) of phenocrysts from the border zones of the granite areas — gradation from an interior porphyritic facies peripherally into an even-granular granite, of coarse texture and the same mineral and chemical composition; (c) the further absence of evidence of magmatic resorption or corrosion of the phenocrysts; and (d) the presence of abundant inclusions of all the ground-mass constituents, characterizing the phenocrysts of the Georgia porphyritic granites,[1] indicate, that the phenocrysts of these granites were developed *in place;* and they are not, according to the old belief, of *intratelluric* origin.[2] That is, the porphyritic feldspars crystallized or grew contemporaneously with the formation of the ground-mass minerals, after the magma had assumed equilibrium — *in place.*

Since the porphyritic granites and the even-granular granites of the State have been shown to represent, in most cases, distinct facies of the same magma, the genesis must necessarily have been the same. The essential difference between the two facies is texture, which is accounted for, on the ground of variation or difference, principally, in the physical conditions obtaining, under which the magma solidified.

[1] Watson, Thomas L., Op. cit., p. 122.

[2] For a discussion of the origin of phenocrysts of intrusive igneous rocks, see Pirsson, L. V., "On the Phenocrysts of Intrusive Igneous Rocks," Amer. Jour. Sci., 1899, Vol. VII, pp. 271–280; Crosby, W. O., "On the Origin of Phenocrysts and the Development of the Porphyritic Texture in Igneous Rocks," Amer. Geologist, 1900, Vol. XXV, pp. 299-310; Cross, W., "Laccolitic Mountain Groups," U. S. Geol. Surv., 14th Ann. Rept., 1895, p. 231; and Zirkel, F., Lehrbuch der Petrographie, 1893, Vol. I, p. 737 *et seq.*

JOINTS AND SLICKEN-SIDES

Scarcely without exception, joint-planes have been observed in most of the larger and principal granite masses in the State. In some of the larger areas, such as the Lithonia granite-gneiss and the Stone Mountain granite residual, while cut by joints, the joint-planes do not form a characteristic feature of the masses, and are by no means so numerous and well developed, as in many granite areas occurring elsewhere in the United States. So far as observation has extended, they form several different series; and, as a rule, they conform more or less to uniform directions throughout the region. The best developed ones have nearly due east-west and north-south courses. In many of the quarries, the major series approximates true northwest-southeast directions.

As to the origin of the joints in these rocks, nothing definite can, as yet, be stated, further than that they are probably due both to contraction of the granite magma on cooling, and to torsion produced by crustal or earth movements.

The form of weathering, more especially of the massive granites, is into large, well rounded, varying sized boulders, strewn over the surface of the region, loose, or partially buried in the residual clay. It is quite evident, therefore, from this, that the rock was jointed, and the planes favoring the ingress of surface water, caused the mass to weather along these natural planes of parting. Atmospheric decay, however, must have taken place more rapidly on the edges and corners, than along the flat sides of the blocks, which resulted in rounding, and forming them into the present-shaped boulders, found generally scattered over the surface, and partially buried in the residual decay.

In these boulder areas, as would be expected, the surface rock is usually found in a partially weathered condition, for some distance down, and care should be used in selecting rock for dimension work. These are merely surface expressions of solid, massive rock beneath; as the quarries, after going down some depth, exhibit solid material, of excellent quality, highly satisfactory for large dimension stone.

Subsequent movement, however, in many of the quarries, is manifest in the smooth and strongly slicken-sided surfaces of the joint-planes. The slicken-sided surfaces occur quite conspicuously developed in the Stone Mountain-Lithonia, and the Hancock-Putnam Counties granite area, where the surfaces of the joint-planes are coated with smooth, somewhat yellowish-colored damourite, frequently more or less grooved and striated from the movement.

DIKES AND VEINS—OCCURRENCE AND DESCRIPTION

Two sets of intersecting material, differing widely in texture and, to some degree, in mineral composition, and differing, also, in origin, are common to the granitic rocks. According to texture and composition, these are divisible into true dikes and veins.

Dikes

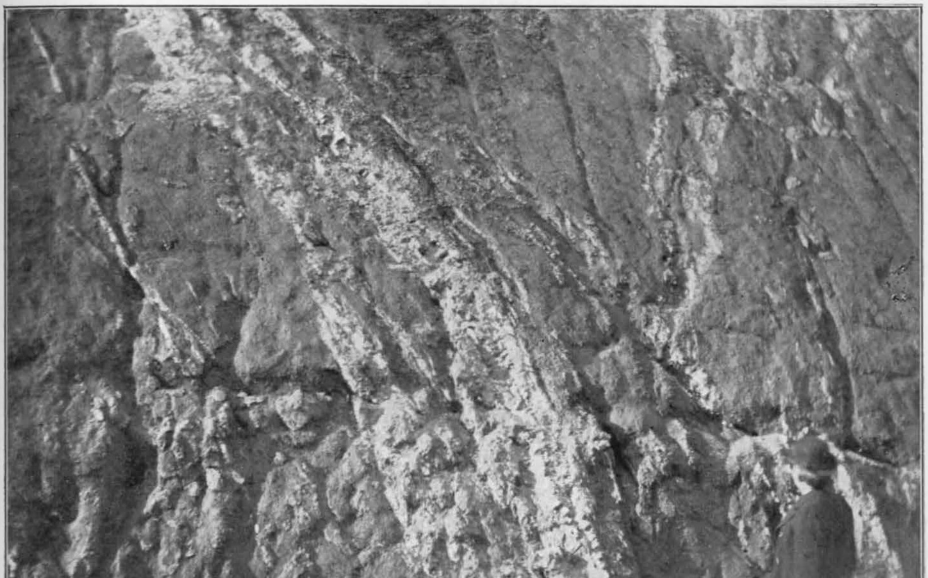
These vary in width, from a few inches to forty feet, and cut the rocks in nearly vertical positions. They are dark blue-gray in color and fine- and even-grained in texture, and are composed of quartz and the feldspars, orthoclase, plagioclase and microcline, with biotite, as the principal minerals. Aside from being somewhat finer textured, they can not be distinguished, in the hand specimens, from granites of the Oglesby and other blue-granite areas in the State. They are common to many of the porphyritic granites and gneisses; but they have not been observed in any of the normal granites. They occur typically developed in the following localities: The Sparta quarries of porphyritic granite, Hancock county; the foliated porphyritic granites (granite-gneisses) of Warren county, near Camak and at Holder's mill; and the Odessa quarry of contorted granite-gneiss in Meriwether county. At Holder's mill, where the public wagon-road crosses Wrightsboro creek, a parallel series of three dikes, from three to four inches wide, occurs within a zone, a few feet in width. Unlike those of the other areas, the dikes here have been thinly laminated, parallel to the walls, from subsequent metamorphism. They project nearly an inch above the surface of the enclosing rock, and well illustrate the difference in weathering of a fine- and a coarse-grained rock.

A chemical analysis of specimens, collected from a 40-foot dike, found cutting the foliated porphyritic granite-gneiss, near Camak, on the Brinkley place, yielded the writer the following results:—

Silica, SiO_2	68.76
Alumina, Al_2O_3	16.80
Iron Sesqui-oxide, Fe_2O_3	0.99
Lime, CaO	2.72
Magnesia, MgO	1.00
Soda, Na_2O	4.82
Potash, K_2O	3.70
Ignition	0.29
Total	99.08

A comparison of this analysis with analyses of the normal (even-granular) granites, reveals practically no difference in the rocks. The acidity, as will be observed, is the same for the two rocks.

Fig. 2



GRANITE DIKES, NEAR ATLANTA, GEORGIA.

Fig. 1. Fine-grained Biotite Granite Dike Cutting Mica-schist, Both the Granite and the Enclosing Schist Being Deeply Weathered.

Fig. 2. Pegmatitic Dikes Cutting Mica-schist, the Enclosing Schist Being Altered to a Ferruginous Residual Clay, in Which the Schistosity of the Fresh Rock is Partially Preserved.

In addition to the quartz, the feldspar species, and the biotite, the microscope showed inclusions of prismatic crystals of apatite and zircon, and drop-like inclusions of quartz and feldspar grains in the larger individuals of these two minerals, along with small rounded areas of micropegmatitic intergrowths of quartz and feldspar. The rock texture is allotriomorphic-granular.

It will be observed, therefore, from the above description, that these rocks are true granite dikes, identical in structure, mineral and chemical composition, with the massive granites. That they have not been found in the true granites; that they cut the adjacent granitic rocks; and that they agree so closely with the massive granites in essential details, is strong evidence of contemporaneity in origin of the two.

APLITE DIKES.—[1] Careful field-study of the larger and principal granite areas of the State indicates the general absence of true aplites therefrom. They have been observed in association with the granite masses, at only one locality, namely, Stone Mountain. It is not possible to say, whether aplites, as border phenomena,[2] are present in the larger granite masses; since their border portions are usually covered to some depth with residual decay.

Several aplite dikes, less than six inches in width, are exposed in the quarries opened on the northwest side of the Stone Mountain granite ridge. The principal aplite in this granite is banded with pegmatite, the aplite forming the border next to the granite, and the pegmatite, the middle layer of the dike. The junctions between the granite, aplite and pegmatite are regular, entirely sharp, and well defined. Apart from its being more compact, and of much finer grain, the aplite is readily distinguished, in the hand specimen, from that of the enclosing granite, by its lighter color (marble white) and by its containing but little mica. Biotite is entirely absent, and muscovite is only sparingly distributed through the rock as minute foils. Occasional small crystals of a red garnet are present.

In thin sections, the aplite shows no essential difference in mineral composition from the granite, except in the entire absence of biotite and in its containing less muscovite. The aplite is a holocrystalline mass, composed chiefly of the potash and soda feldspars and quartz. Microperthitic structure, consisting of interlaminated orthoclase and microcline with a second feldspar,

[1] Watson, Thomas L., Journal of Geology, 1902, Vol. X, pp. 186–190.

[2] Kemp, J. F., Bulletin, Geological Society of America, 1899, Vol. X, p. 372.

albite, is common. Somewhat irregular, stout laths of well striated acid oligoclase are numerous. The small percentage of calcium oxide, CaO, less than 1 per cent., and the greater percentage of soda, Na_2O, shown in the analysis below, indicates the preponderance of the soda molecule (albite). This is corroborated by the microscope. Sporadic inclusions of apatite occur.

The following analysis of specimens of the Stone Mountain aplite was made by the writer in the chemical laboratory of Denison University, Granville, Ohio: —

		Molecular Ratios
SiO_2	74.30	1.2383
TiO_2	none	——
Al_2O_3	14.73	.1444
Fe_2O_3 [1]	0.78	——
MnO	trace	——
CaO	0.90	.0161
BaO	none	——
SrO	none	——
MgO	strong trace	——
Na_2O	4.61	.0743
K_2O	4.52	.0481
H_2O (Ignition)	0.21	——
P_2O_5	trace	——
Total	100.05	

Calculating all the lime as anorthite, all the soda as albite, and all the potash as orthoclase or microcline, the mineral composition of the aplite becomes: —

Potash-feldspar	26.69	per cent.
Soda-feldspar	38.77	" "
Lime-feldspar	4.45	" "
Quartz	28.30	" "
Excess of Al_2O_3	0.61	" "
Excess of Fe_2O_3	0.78	" "
Excess of H_2O	0.21	" "
Total	99.81	" "

From the above calculations, the ratio of soda feldspar to lime feldspar is 9 : 1, corresponding to lime-bearing albite of Ab_9An_1, when the albite and anorthite molecules are combined to form soda-lime plagioclase. The relative abundance of the constituents in the aplite may be expressed as follows: Oligoclase > quartz > orthoclase and microcline > muscovite.

[1] All iron was determined as ferric oxide.

VEINS

The class of material, designated under this heading, differs from the true granite dikes described above, principally in texture and, to a less degree, in mineral composition. Some are true pegmatitic intrusions, of aqueo-igneous origin; while others are as certainly true veins of segregation. They are common to the three rock-types, porphyritic and non-porphyritic granites and granite-gneisses, and are equally characteristic of each. They are characterized by the usual extremely coarse-grained pegmatitic structure, and are composed almost exclusively of large, lustrous and cleavable pink tinted and white feldspar, with some quartz, and a much smaller proportion of black biotite, and occasionally, muscovite. In some cases, they are very extensive, and are apparently deep seated; while, in others, they are very limited in extent, and are entirely surrounded by the granite. They are very irregular in outline, conforming to no uniform orientation, but cutting the rock in numerous directions, and at various angles.

Thin sections of several of these masses revealed microcline, orthoclase and plagioclase, with occasional microperthitic structure, a few shreds of biotite, and some quartz, under the microscope. Hand specimens of others showed nearly equal proportions of feldspar and quartz, with occasional biotite plates.

AGE OF THE GEORGIA GRANITES [1]

No sedimentary rocks, whose age is definitely known, occur in the Georgia Piedmont region, to aid in the positive determination of the age of the granites. In the absence of these, we can only hope to arrive at their relative ages, by careful study of the contacts, and the relative amounts of dynamic metamorphism, they have suffered. Several elements, of considerable importance, bearing on the age of the rocks in this section, seriously militate against obtaining thoroughly satisfactory results. These are, first, the lack of detailed mapping and thorough laboratory study of the various rocks in general; and, second, the prevailing depth, to which the unaltered rock is covered with residual decay, necessarily masking a great deal, that is absolutely necessary to a correct interpretation of the rock structure etc.

Granitic rocks are very prevalent throughout the Atlantic Seaboard, extending from Nova Scotia to Alabama; and, in many

[1] Watson, Thomas L., The Granitic Rocks of Georgia and Their Relationships, Amer. Geologist, 1901, Vol. XXVII, pp. 199–225, especially pp. 223–225.

cases, their igneous origin has been proved beyond question. They are known to range in age, from the Archæan up to the close of the Carboniferous,[1] when intrusion was contemporaneous with the Appalachian upheaval.

The Piedmont region in Georgia represents an old dissected mountain system, which has passed through at least two periods of general base-leveling, accompanied by as many elevations; and, at the present time, it is being eroded again. A careful field examination of the granitic rocks, occurring in the State, shows considerable contrast in the amount of foliation and banding secondarily induced by pressure. No specimen of these rocks examined is entirely free from the effects of mechanical strain. In every thin section, studied under the microscope, more or less distinct traces of dynamo-metamorphism are recognized. The quartz exhibits undulatory extinction,[2] and, with the feldspars, is crossed by numerous lines of fracture. In many cases, the quartz and feldspar are frequently peripherally shattered, with the fragments thus derived, forming variable-sized borders of the fine-grained mozaics of the two minerals, around and between the quartz and feldspar individuals.

The granite-gneisses differ from the massive phases of the rocks, simply in the more marked foliated structure. In the partial crushing of the quartz and feldspar, their parts have not been separated in any of the thin sections of the rocks examined. In many of the typical areas of the massive granites, an incipient gneissoid structure is partially indicated, and thin sections of the same rock display undulous extinction, lines of fracture crossing the quartz and feldspar, and occasional peripheral shattering.

While various degrees of foliation in the granitic rocks are represented, it is very generally true, that the banded type, gneiss, has reached the limit in structure, which is most typically developed. No case has been observed in the field, where the highly contorted gneissoid phase could be definitely traced into the massive type;[3] but, on the contrary, there appears to be, in most cases, a sharp line of demarkation between the massive and slightly

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[1] Pirsson, L. V., Amer. Jour. Sci., 1893, 3rd Series, Vol. XLVI, 363-378.

[2] According to McGee (7th Ann. Rept., U. S. G. S., 1889, p. 619), crustal movement is at present active in the Piedmont region; and a part of the optical (microscopical) disturbances in the quartzes of the massive granites may be due, in some degree, to this period of movement.

[3] Dr. Hayes has described a large area of porphyritic granite in Bartow county, Georgia, near the Cartersville fault, in which a pronounced foliated structure is visible in most of the mass, but grading into somewhat massive granite in places. The stratigraphic relations of this mass to the surrounding sedimentaries of known age cannot be mistaken; and, as Hayes has pointed out, the granite is pre-Cambrian (Archæan) in age, and is rendered schistose by subsequent intense metamorphism. *Trans., Amer. Inst. Min. Engrs., Washington Meeting, February, 1900.* There are other areas in the western Piedmont-complex, which represent beyond doubt, transitional phases of the massive and foliated granites; but, on account of lack of exposures, the gradation could not be definitely traced in the field.

gneissoid granites, and the extreme typically foliated granite-gneisses. This contrast is very strikingly illustrated, in the case of the Stone Mountain granite, which is slightly gneissoid in structure, and the highly contorted gneisses, of similar composition, in the Lithonia region. No apparent gradation is traceable, from one to the other; but the contact between the two is very sharp. Also, the same abruptness in contact exists, in this locality, between the Stone Mountain granite and the mica-schist, and between the Lithonia contorted granite-gneiss and the mica-schists.

In other areas, notably those of Meriwether and Warren counties, where the typical banded and massive phases of the granitic rocks occur, a part of the granite-gneisses are cut by true granite dikes, varying in width, from an inch to thirty feet, and having the same chemical and mineralogical composition, as the massive granites, which they resemble in every respect. Hand specimens of some of the dike material cannot be distinguished from those of the massive granite areas. Owing to the deep covering from residual decay, the dikes found cutting some of the granite-gneisses could not be definitely traced to the massive areas of the rock; but the field evidence very strongly indicates, that they are apophyses from the true granites, and they are so regarded by the writer.

In the light of these facts, if schistose structure, or the degree of metamorphism, be taken as a criterion, or index, of age-relationship, in the case of the Georgia granitic rocks, and the evidence, so strongly pointing to an igneous origin for the highly banded gneisses, be accepted, at least two distinct periods of intrusion of closely similar acid material are represented in this area. No attempt is made, in this report, to work out the relations of the acid to the basic eruptive rocks. The surrounding schists are certainly older than the granites; since dikes of the latter rocks are found cutting the former, in great numbers. As to the origin of the schists, nothing is yet positively known.

Field and laboratory study certainly indicates, that the different granitic masses, here mentioned, were not contemporaneous as to origin. Most, if not all, of them were certainly pre-Cambrian, while others may possibly have been later. They could not have been later, however, if as late, which appears improbable from the existing facts and conditions, than the last great disturbance in the region, preceding the Appalachian uplift; as Mesozoic eruptives are found cutting the granitic rocks, in several instances. A careful field-study of this section indicates, that a majority of the gneisses were contorted and folded, before the later granites made their appearance. A very close relationship, in mineral and chemical composition, to similar rocks existing to the north, in the Atlantic Coast region, is observed in the Georgia granites. Kemp,[1] after a careful study of our present knowledge of the Atlantic Coast granites, has emphasized the great predominance of mica granites, especially the biotitic types, over others; and, with other investigators,[2] he has remarked their definitely known intruded character at different geological periods. Keyes[3] has shown, that the acid eruptives (granites) of the Piedmont region in Maryland "were among the last igneous intrusions to disturb the rocks of the eastern Piedmont Plateau." This prompts the query: Were not a part of the Georgia acid eruptives (granites) to the south, contemporaneous in origin with the Maryland granitic intrusives?

Field and laboratory study of the granitic masses in the Georgia area certainly indicate, that they were not all contemporaneous in origin. As already stated, some of them are pre-Cambrian, while others may possibly be later in age.

After a study of the Newark rocks of the "Richmond basin" in Virginia, Shaler and Woodworth,[4] in commenting on the age of the underlying rocks, or "fundamental plexus," including granites and gneisses, say, on page 418: "——they probably date to Laurentian or Huronian time." Again, on page 421, of the same report, the authors say: "The age of these rocks [granites and gneisses] is not locally determinable." The granites and gneisses of this area were grouped by Rogers[5] as Archæan.

Not until an exhaustive study of the various rocks, comprised within the limits of the so-called Crystalline Belt of Georgia, is made, and detailed mapping is executed on a large scale, can we hope to look for definite information regarding the exact age of the granitic rocks. Whatever the ages of the granites of this area may be, it is certain, that the most massive types of the rocks display strong proofs of mechanical strain, indicating, therefore, that, since the intrusion of the last granites, the region has suffered profound dynamo-metamorphism.

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1 Kemp, J. F., Bulletin, Geol. Soc. Amer., 1899, Vol. X, pp. 378-382.

2 Williams, G. H., 15th Ann. Rept., U. S. Geol. Surv., 1893-'94, pp. 666-670. Dr. Williams reviews the distribution and relative ages of igneous granites of the Appalachian crystalline belt, and gives numerous bibliographic references thereto.

3 Keyes, C. R., 15th Ann. Rept., U. S. Geol. Surv., 1893-'94, p. 733.

4 Shaler, N. S., and Woodworth, J. B., 19th Ann. Rept., U. S. Geol. Surv., 1897-'98 (1899), Part II pp. 385-515.

5 Rogers, Wm. B., Geology of the Virginias, 1884.

VIEW OF A PART OF THE CHILDS QUARRY, NEAR OGLESBY, GEORGIA, SHOWING VEINS OF PEGMATITE CUTTING THE GRANITE.

ORDER OF SEPARATION OF THE COMPONENT MINERALS IN THE GEORGIA GRANITES

So far as is revealed by the microscope, the order observed in the crystallization of the various minerals, in the Georgia granitic rocks, is the same as for normal granites having a similar composition, occurring elsewhere. The most basic and idiomorphic minerals, apatite and zircon, and iron oxide when present, were the first to separate from the cooling magma, followed by less idiomorphic biotite and basic plagioclase. The growth of the potash feldspars, orthoclase and microcline, was interrupted by that of the quartz; and numerous micropegmatitic intergrowths of the feldspar and quartz occur, in a majority of the thin sections. This evidence of contemporaneous crystallization in the feldspar and quartz, is manifest in each of the three rock-types — to a less degree, however, in the gneisses than in the even-grained granites and their accompanying porphyritic facies. The earlier crystallizations, including apatite, the iron ores when present, zircon, biotite and basic feldspar, are wholly or partially idiomorphic in crystal outline; while the acid potash feldspars rarely display idiomorphic tendencies. As the last product of crystallization, the quartz always occurs as irregularly bounded, or allotriomorphic, grains.

The relative abundance of the principal constituents in the granitic rocks may be expressed as follows: Feldspar, including all varieties present > quartz > biotite.

CHAPTER V

PART I

THE GENERAL PRINCIPLES OF ROCK-WEATHERING

Rocks are composed of one or more minerals, each of which is expressed by a definite chemical formula. The stability of these chemical compounds is controlled by the prevailing conditions. Manifestations of the unstable condition of the compounds, entering into the composition of the earth's crust, are abundant on every hand. Readjustments are constantly taking place, involving forces, which are, in part, physical and, in part, chemical. The process employed may be simple or complex, and confined within the limits of the surface zone; or it may be deep-seated. Weathering involves only those processes, which are atmospheric (external agencies) and is confined to all land-surfaces above sea-level, embracing only those changes, effected within the surface zone of oxidation. The forces operating become quite, if not entirely inactive, at comparatively slight depths. Unless removal keeps pace with degeneration, a limit must be reached, theoretically, where the work wrought by the meteoric agencies would be nothing. If, however, retardation is prevented by the degenerated (weathered) rock being removed at a rate comparable with the forces involved, thousands of feet of earth strata may be eroded and carried seaward.

The term, *weathering*, as applied to rocks, includes those changes wrought on the earth's surface through agencies, which may be grouped under the two general headings, (a) mechanical, and (b) chemical. The changes, brought about, consist mainly in the breaking down of the more complex and less stable bodies (fresh rock) into residual products, of a less complex and more stable character — a readjustment, in other words, from unstable to stable compounds. The processes, involved in this approximately complete change of the fresh rock as a geologic body, are usually more or less complex.

When exposed, for a sufficient length of time, to the atmospheric agencies, all rocks undergo a process of disintegration and decomposition, commonly known as *weathering*. As a result of the operation of these forces, the fresh rock is converted superficially into clay, sand, and larger fragments, more or less stained and colored by the iron oxide present, yielding finally a soil, which has been described by Merrill,[1] as a "transitory phase of this weathering process." This mantle or covering of loose and incoherent material is constantly borne seaward by erosive agents, to be consolidated into various beds of sedimentary rock, of varying thickness, and again to be raised above sea-level, when atmospheric work begins anew. Thus we have, so to speak, a never ceasing or ending cycle of attack.

Since the physical and chemical agencies, involved in the processes of weathering, mutually combine in breaking down rock-masses, they may be grouped together and treated under the following three general headings: (a) action of the atmosphere; (b) action of water in the solid and liquid form; and (c) action of plant and animal life.

ACTION OF THE ATMOSPHERE.—In its normal condition, the atmosphere is essentially a mechanical mixture of nearly four volumes of nitrogen, 79.4 per cent., to one of oxygen, 20.6 per cent., with small and varying amounts of several other gases, the chief of which is carbonic acid gas, present in amounts varying from 2.5 to 3.5 parts in 10,000.

In the vicinity of large cities and volcanic regions, hydrochloric and sulphuric acids, probably in combination, at times, as salts of the two acids (chlorides and sulphates) are present in somewhat appreciable quantities. These localities form, comparatively speaking, so small a percentage of the whole, that the two last named acids and their salts may not be considered.

When pure and dry, and under constant conditions of temperature and pressure, air has practically no effect as a rock-destroyer, either by chemical or physical action. Moisture, however, is always present in the atmosphere, in varying proportions, ranging from the point of saturation and supersaturation, when precipitation takes place, to a minimum point. When aided, on the other hand, by moisture and temperature changes, the atmosphere is rendered a most active and effective agent in the disintegration of rock-masses. As a geologic agent, the atmosphere works destruction on rock-masses—chemically, by action of its gases and vapors, and mechanically, by temperature changes and motion.

[1] Maryland Geological Survey, Volume II, Part 2a, 1898, p. 57.

Nitrogen. — Since the properties of this element were first made known, chemists have regarded the elementary nitrogen in the atmosphere as wholly inert. Under certain conditions, however, compounds of nitrogen with hydrogen and their oxygenated equivalents are accompanying products of organic decay. Nitrous[1] and nitric acids, resulting through the agency of bacteria in the soil, are formed; but, on account of slight occurrence, they probably do not exert any general direct influence on rock decomposition. In addition, local electrical disturbances result in the formation of minute quantities of free nitric acid in the atmosphere.

Oxygen. — This is chemically the most active principle of the atmosphere. The process of oxidation is effected by means of this element. Owing to the affinity, which most minerals possess for oxygen, the decomposition of those silicates and other minerals, containing protoxide bases, especially iron, is chiefly promoted by the process of oxidation. This action, however, is greatly limited, in the absence of moisture.[2]

Carbonic Acid. — The very general and wide-spread distribution of this gas, CO_2, in the atmosphere, and its being readily dissolved and brought to the earth's surface by every rain and snow, seem to have been pretty generally urged, as reasons for its being one of the main factors concerned in rock decomposition. The amount present in the atmosphere, while somewhat variable, is very uniformly distributed, except in the immediate vicinity of vocanoes and gaseous springs, and, probably, large cities. The following tabular statement will give some idea, as to its distribution, as compiled and quoted from various authorities by Merrill:—[3]

385	parts	of	CO_2	in	1,000,000,	in	spring of 1870,	in Boston
337	"	"	"	"	"	"	"	Cambridge
387 to 448	"	"	"	"	"	"	"	Washington
442	"	"	"	"	"	"	"	Manchester, England

Müntz and Aubin,[4] after a number of determinations for the atmosphere in Florida, Mexico, Haiti, Chili and Patagonia, found an average of 278 parts in 1,000,000, and, for northern France, 296 parts in 1,000,000. Fisher is quoted by Brauner,[5] as showing the distribution in rain and snow water to vary between 0.22 and

[1] Wiley says: "The ammonia and nitrous acid may not appear in the soils, as the nitric organism attacks the latter at once, and converts it into nitric acid." *Principles and Practice of Agricultural Analysis*, by H. W. Wiley.

[2] See further, under the chemical action of water, pages 289 and 290.

[3] Merrill, George P., Jour. of Geol., 1896, Vol. IV, p. 709. Also, Rocks, Rock-Weathering and Soils, by George P. Merrill, 1897, pp. 179–180.

[4] Bull., Geol. Soc. Amer., 1896, Vol. VII.

[5] *Comptes Rendus*, 1881, Vol. XCIII, p. 797; *Ibid*, 1883, Vol. XCVI, pp. 1793-1797.

0.45 per cent. by volume of water. As Merrill states, taking the general mean of these results to represent the amount of CO_2 present in the air, and knowing the annual precipitation for any given section, it becomes simply a matter of computation, to calculate the amount of CO_2 brought annually to the surface, for that locality. The action of this acid on various mineral species has been well shown by the researches of Daubrée, T. Sterry Hunt and the Rogers Brothers.

Temperature Changes — Heat and Cold. — It is a well known law in physics, that temperature changes produce expansion and contraction — *heat*, expansion, and *cold*, contraction. Rocks are made up of an aggregate of minerals, each having its own degree of expansion and contraction, when exposed to temperature changes. Unequal expansion and contraction of the individual minerals, result both from diurnal and seasonal changes of temperature. In the crystalline rocks, the mineral particles are crowded in close juxtaposition. A majority of the mineral species have unlike directions through their crystalline grains, which behave differently towards physical agencies along the unlike directions. It follows, therefore, that, when the temperature rises, the minerals expand and crowd irresistibly against each other; whilst, if the temperature lowers, they contract and draw farther apart from one another. A certain strain is thereby induced, as a result of this contraction and expansion, which, in time, will work serious result to the rock.

The co-efficient of cubical expansion for some of the most common rock-forming minerals has been determined as follows: —[1]

Quartz	.0000360	Beryl	.0000010
Orthoclase	.0000170	Tourmaline	.0000220
Adularia (Feldspar)	.0000179	Garnet	.0000250
Hornblende	.0000284	Calcite	.0000200

It will be observed from these figures, that quartz has a co-efficient of expansion slightly more than double that of orthoclase, and approximately one-third greater than that of hornblende. As shown by the researches of Pfaff and Kopp, compiled by Clarke,[2] the matter becomes further complicated by each mineral expanding unequally along the directions of its axes. The co-efficient of expansion for quartz, parallel to the major axis, is .00000769, while, perpendicular to this axis, it is .00001385. In the same way, adularia gives .0000156, .000000659 and .00000294 for the three axes; while hornblende gives, for the same axes, .0000081 .00000084 and .0000095.

[1] Clarke, F. W., Constants of Nature, Smithsonian Miscel. Coll., 1876, Vol. XIV, Part III

[2] Constants of Nature, Smithsonian Miscel. Coll., 1876, Vol. XIV, Part III.

The amount of expansion and contraction, per degree of temperature, has been determined by various workers for several kinds of rock. W. H. Bartlett gives the following, as the average ratio of expansion per inch, for the following named stones, per each degree, Fahrenheit: —[1]

Granite	.000004825 inch
Marble	.000005668 "
Sandstone	.000009532 "

After making similar experiments, Adie obtained the average rate of expansion for the following stones to be: —[2]

Granite	.00000438 inch
Marble (White)	.00000613 "

Calculating the amount of expansion, based on the above figures, for each of the above mentioned stones, a granite block, 12 inches long, raised from a temperature of 32° F., in winter, to that of a summer heat of 95° F., would expand .0035+ inch, and would then be 1 foot, .0035+ inch in length. In the same way, for marble, there would be an expansion of .0042+ inch, and an increased length of 1 foot, .0042+ inch; and for sandstone, an expansion of .0072+ inch, and an increased length of 1 foot, .0072+ inch.

While these figures indicate only a very small degree of expansion; if continued, from season to season, through a long lapse of time, the weakening effect produced will have an appreciable bearing upon the economic importance of the stone. Accepting, therefore, the former figures as being correct, and assuming the maximum range in temperature for Atlanta to be 115° F., there will be found a total difference of 0.66585 inch, in the height of a granite shaft, 100 feet high. It can readily be seen, from these figures, that the result of such strain on granite will, in time, cause considerable wear and tear. Moreover, for the other stones, above mentioned, this strain will be greater, and they will yield more readily than granite to such forces, other things being equal. Such action will eventually result in opening invisible cracks and crevices in the rock; or, it may be, in pulling the stone away from the cement. This will form ready channel-ways for water, and thereby open up the way for decay.

In some localities, where the diurnal range in temperature is very great, masses of varying sizes are disrupted from the parent ledges. H. vonSteeruwitz states,[3] that, in the Trans-Pecos region

[1] Amer. Jour. Sci., 1832, Vol. XXII, p. 136.

[2] Trans., Royal Soc., Edinburgh, Vol. XIII, p. 366.

[3] 4th Ann. Rept., Geol. Surv. of Texas, 1892, p. 144.

of Texas, where variations in diurnal temperature amount to as much as from 60° to 75° F., the rock is rapidly disintegrated from this cause. Livingstone states,[1] that, in some parts of Africa, the rapid cooling by radiation of the rock-surface, after reaching a very high degree of temperature during the day, results in breaking off, by contraction, masses as large as 200 pounds in weight. Stanley, further, observed,[2] that the cold rain, falling on these highly sun-heated rocks in Africa (137° F., according to Livingstone), caused them to split off. Merrill cites similar results,[3] wrought on the granitic and basic eruptive rocks of the desert regions of Lower California. Disintegration, from this cause, however, is limited almost wholly to the surface of the rock, owing to the low heat-conducting power of rocks in general.

Wind.—In many parts of the world, the air set in motion becomes a potent means of removing the loose covering. Mr. Flinders Petrie is quoted by Sir A. Geikie,[4] as stating, that about eight feet of soil has been swept away from some parts of the delta of the Nile, by the wind, within the last 2,600 years—approximately four inches per century. Not only is the wind engaged in the removal of the loose material; but the constant driving, with such violence, renders it a very effective means of wearing away or rubbing down the rock surfaces by mechanical abrasion. The etching and engraving of glass by artificial sand-blasts well illustrates the nature and potency of this agent. Many authors have put on record the work wrought by this agent. J. Walther has described[5] the polishing effect of the wind-blown sand on the Egyptian monuments; M. Choisy noted similar action on the rocks,[6] by the blown sand of the Sahara; G. K. Gilbert has observed the peculiar wearing away, from the erosive action of the wind, of the blocks of sandstone and limestone in the Western United States;[7] Endlich has noted some interesting results wrought by wind action on rocks in Colorado;[8] and Prof. Egleston observed, that the grave-stones in many of the church-yards of New York City are worn nearly smooth, and the inscriptions, rendered almost illegible, by this agent.[9] A comprehensive review of the sub-

1 Livingstone's "Zambesi," pp. 492, 516.

2 Proc., Roy. Geog. Soc., 1876, Vol. XX, p. 142.

3 Rocks, Rock-Weathering and Soils, 1897, p. 183.

4 Text-Book of Geology, 1893, 3rd Edition, p. 329; Proc., Roy. Geog. Soc., 1889, p. 648.

5 Quoted by Sir A. Geikie, *Ibid.*, p. 330.

6 *Ibid.*, p. 330.

7 Wheeler's Report of U. S. Geograph. Surv., W. of 100th Meridian, Vol. III, p. 82.

8 Bull., U. S. Surv. Ter., 1878, Vol. IV, pp. 831-864.

9 Amer. Arch., 1885, Sept. 5, p. 13.

ject of wind erosion has been published by Udden, in the Journal of Geology.[1]

The work accomplished by this agent is naturally most effective in arid regions, which are generally characterized by an almost total absence of vegetation. Its effects, however, are oftentimes present in our humid Atlantic coast climate, where the beach-sands are caught up and driven, with much violence, before the wind. In the case of one of the light-houses on Cape Cod, the impact of the wind-driven sand was so great on the heavy glass in the windows, as to render some of them no longer transparent, necessitating their removal, in a few instances.

Naturally, the action resulting from this agent is a very slow one; but, after long lapses of time, and under constant blast, the effects are manifest.

Chemical Action of Water. — Water is by far the most important of all the meteoric agents, that tend to modify the earth's surface. It is now very generally agreed, that there is probably no mineral substance, which, when under proper conditions, is not to some degree soluble in pure water. The investigations, many years ago, of Profs. W. B. and H. D. Rogers,[2] and the more recent researches of Daubrée and Cossa, prove conclusively, that the common mineral species of rocks are quite appreciably soluble in distilled water, the solvent action of which, however, is greatly accelerated by the presence of carbonic acid. Water in the pure form, however, does not exist in nature; but it is always charged with certain gaseous and solid products, absorbed and abstracted from the atmosphere, in its descent to the earth. Rain-water has been shown to contain in solution about 25 cubic centimeters of gases per liter. Sir A. Geikie says:[3] "An average proportional percentage is by measure—nitrogen, 64.47; oxygen, 33.76; carbonic acid, 1.77."

In 1898, Prof. F. W. Clarke conducted a series of tests,[4] seeking the solubility of certain silicates in pure water. Tests were made on twenty-two different species, using phenol-phthalein as an indicator, the solubility being noted by the alkalinity of the powdered mineral in distilled water, in the presence of the above indicator. The following silicates were tested, giving more or less decided reaction, which indicated some solution in each case: Muscovite, lepidolite, phlogopite, orthoclase, oligoclase, albite, leucite, nephelite,

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[1] Jour. Geol., 1894, Vol. II, p. 315.

[2] Amer. Jour. Sci., 1848, Vol. V.

[3] Text-Book of Geology, 1893, 3rd Edition, p. 341.

[4] Clarke, F. W., The Alkaline Reaction of Some Natural Silicates, Jour. Amer. Chem. Soc., 1898, Vol. XX, pp. 739–742.

Fig. 2

RESIDUAL CLAYS DERIVED FROM THE DECAY OF GNEISS, NEAR ATLANTA, GEORGIA.

Fig. 1. A Thirty-foot Section of the Vari-colored Clay.
Fig 2. A Forty-foot Section of Clay, in Which the Original Schistosity Planes of the Fresh Rock Are Perfectly Preserved.

cancrinite, sodalite, spodumene, scapolite, laumontite, stilbite, chabazite, heulandite, thomsonite, analcite, natrolite, pectolite, apophyllite and ægirite.

Other substances than gases occur in smaller quantities; and, after reaching the earth's surface, more or less organic matter is dissolved, among which is a group of organic acids, numbering half-a-dozen or more, which greatly increase the chemical action of the water. The following is a chemical analysis of rain-water, collected near London, England, and quoted by Prof. I. C. Russell[1] as showing the amount of matter commonly occurring in solution: —

Organic Carbon	0.99 part in 1,000,000 of water
Organic Nitrogen	0.22 " " " " "
Ammonia	0.50 " " " " "
Nitrogen, as Nitrates and Nitrites	0.07 " " " " "
Chlorine	6.30 parts " " " "
Total Solids	39.50 " " " " "

The chemical work, promoted by water, may be treated under the following headings: Oxidation, Deoxidation, Solution and Hydration.

Oxidation. — The frequent occurrence of ferrous and manganous compounds, existing as constituents of minerals, are especially liable to oxidation, on account of their strong affinities for combining with more oxygen. In fact, all rocks, which carry iron in the form of sulphide, protoxide, carbonate or silicate, are affected by this change. Among the most commonly occurring minerals as constituents of the principal rock-types, and, therefore, of wide distribution, are the ferro-magnesian silicates, representing the three following important groups of minerals; namely, the pyroxenes, the amphiboles and the micas. The principal cause of weathering in these, is largely the affinity of the iron, in the ferrous condition, for oxygen, resulting ultimately in a chemical combination of these two, forming the peroxide, or ferric oxide, and accompanied by hydration. The bright red and yellow colors of the residual products, from rocks containing these minerals, are due to this cause. Another frequent and familiar example of oxidation is that of the iron sulphides, pyrite and marcasite, especially the former. These are common constituents of many rocks. The iron becomes oxidized, with liberation of sulphuric acid, and passes over into the hydrated sesqui-oxide (limonite), manifested in the yellowish brown staining of the rock surface. If in large enough quantities, the sulphuric acid becomes immediately a free destroyer of the rock, in which the mineral liberating it occurs. The first stage in the oxidation of the sulphides is the formation of the sul-

[1] Rivers of North America, 1898, p. 75.

phates, which is attended by an increase in bulk, which becomes at once a physical force in aiding rock disintegration.

Deoxidation. — When carrying organic matter in solution, water becomes a reducing agent, in that its affinity for oxygen, through the dissolved organic material, reduces the peroxides to the protoxide state. This action has been particularly noticeable, in the case of the iron oxides. The so-called bog-iron ore has, in many instances, been the direct result of the waters, charged with organic matter, dissolving the iron out of the soil and rocks, through which they percolate; the iron salt being again oxidized and precipitated, upon favorable conditions. The existence of beds of iron ore among sedimentary rocks is believed by some to afford strong testimony of the contemporaneous existence of organic life, whereby the iron was leached out and subsequently precipitated. Deoxidation is especially noticeable in some of the red sandstones, so colored by iron oxide, probably hematite, where white spots and streaks occur, due to a dissolving out, in places, of the ferric oxide by percolating waters, holding organic matter in solution. By a similar process, ferrous sulphates may be converted into sulphides. Deoxidation, it will be observed, is of less frequent occurrence than oxidation.

Solution. — The solvent action of water is probably one of the most wide-spread phenomena among the natural processes, although attended at times by many complex chemical changes. Only a very few minerals are readily soluble in water, without chemical change, the action being promoted, in the majority of cases, by the water carrying in solution certain gaseous compounds, such as carbonic acid and the organic acids (humic, ulmic, crenic and apocrenic acids). In 1848, the Rogers Brothers, as stated elsewhere, showed the power of pure water to appreciably dissolve all commonly occurring silicates; and that, within less than ten minutes, the action of carbonated water on the same mineral species was recognizable.[1] "By digestion for forty-eight hours they [Rogers Brothers] obtained from hornblende, actinolite, epidote, chlorite, serpentine, feldspar, etc., a quantity of lime, magnesia, oxide of iron, alumina, silica, and alkalies amounting to from 0.4% to 1% of the whole mass. The lime, magnesia, and alkalies were obtained in the form of carbonates; the iron, in the case of hornblende, epidote, etc., passing from the state of carbonate to that of peroxide during the evaporation of the solutions. * * * Forty grains of finely pulverized hornblende, digested for forty-eight hours in carbonated water at a temperature of 60°, with repeated agitation, yielded —

[1] Amer. Jour. Sci., 1848, Vol. V, pp. 401-405

Silica	0.080 per cent.
Oxide of iron	0.095 " "
Lime	0.130 " "
Magnesia	0.095 " " with

traces of manganese." [1]

Merrill also states, [1] that Bischof comments on these results as follows: "——by repeating this treatment 112 times with fresh carbonated water, a perfect solution might be effected in 224 days." Bischof says, further: [2] "If, now, 40 grains of hornblende unpowdered, in which, according to the above assumption, the surface is only one ten-millionth of the powdered, were treated in the same way, and the water renewed every two days, the time required for perfect solution would be somewhat more than six million years."

Turner quotes the following results on the relative solubility of some of the feldspars in pure water, tested by Steiger: [3] "One-half gramme of three powdered feldspars were kept for one month, separately in 50 cm. of distilled water at 70° F., which yielded on analysis:—

Orthoclase	0.16 per cent. K_2O dissolved
Albite (Amelia Co., Va.)	0.07 per cent. Na_2O "
Oligoclase (Bakersville, N. C.)	0.09 per cent. Na_2O "

As Turner says, "This would show a greater solubility for orthoclase than for albite." Results are also given on the relative solubility of two species of feldspar in carbonated water, obtained by R. Müller:—

	SiO_2	Al_2O_3	K_2O	Na_2O	CaO
Orthoclase (Adular)	.1552	.1368	1.3527	———	trace
Oligoclase	.2370	.1713	———	2.367	3.213

In commenting on these results, Turner says: "It is clear here that the soda of the oligoclase is more soluble than the potash of the orthoclase, and that the lime of the oligoclase is more soluble than the alkali."

In order that some idea may be had of the total amount of solids in solution, carried by some of the larger rivers, the following table is appended:—[4]

Rhine	5,816,805 tons per year
Rhone	8,290,464 " " "
Danube	22,521,434 " " "
Thames	613,930 " " "
Nile	16,950,000 " " "
Croton	66,795 " " "
Hudson	438,000 " " "
Mississippi	112,832,171 " " "

[1] Merrill, Geo. P., Rocks, Rock-Weathering and Soils, 1897, p. 191.
[2] Chemical and Physical Geology (English Edition), 1854, Vol. I, p. 61.
[3] Jour. of Geol., 1899, Vol. VII, pp. 398–399.
[4] Russell, I. C., Rivers of North America, 1898, p. 79.

Prof. Russell has further compiled a table, showing "Material in Solution in One Cubic Mile of Average River-water,"[1] which for convenience is here given:—

Constituents	Tons in One Cubic Mile
Calcium Carbonate ($CaCO_3$)	326,710
Magnesium Carbonate ($MgCO_3$)	112,870
Calcium Sulphate ($CaSO_4$)	34,361
Calcium Phosphate ($Ca_3P_2O_8$)	2,913
Sodium Sulphate (Na_2SO_4)	31,805
Potassium Sulphate (K_2SO_4)	20,358
Sodium Nitrate ($NaNO_3$)	26,800
Sodium Chloride ($NaCl$)	16,657
Lithium Chloride ($LiCl$)	2,462
Ammonium Chloride (NH_4Cl)	1,030
Silica (SiO_2)	74,577
Ferric Oxide (Fe_2O_3)	13,006
Alumina (Al_2O_3)	14,315
Manganese Oxide (Mn_2O_3)	5,703
Organic Matter	79,020
Total Dissolved Matter	762,587

Müller has pointed out,[2] that the action of carbonated water on minerals is so energetic, that, after a period of seven weeks, a quantitative estimation could be made of the dissolved material. Some of the principles brought out by Müller in his investigation, are:—

1 All the minerals tested were acted on by the carbonated water.

2 Increase of pressure proved more effective on solution than the prolongation of time.

3 Magnetic iron (magnetite) was least acted upon, of all the minerals tested, and olivine was the most readily soluble of all the silicates tested.

Furthermore, that hornblende was decomposed more readily than feldspar.

Of all stones, ordinarily used for building purposes, limestone suffers the most from solution, its solubility being given in the ratio of 1 to 1,000 parts in water charged with carbonic acid. This is made the more apparent, when it has been shown, that the total solids, calculated in both European and American river-waters, is 0.1888, and of calcium carbonate (limestone), 0.088765 part per thousand. These figures show, that, for normal rivers, the calcium carbonate is approximately one-half of the total solids. The cementing material of some sandstones is dissolved by atmospheric water, causing the rock to crumble into loose sand.

[1] Rivers of North America, 1898, p. 80. [2] Tschermak's Min. Mittheilungen, 1877, p. 25

Some experiments on the rate of weathering of limestone have been conducted by Pfaff,[1] resulting in a calculated loss by weathering of about one meter (39+ inches) in 72,000 years, which is approximately equivalent to one foot in 21,300 years. In England, the rate for the same rock, dressed, has been placed much lower, varying, for one foot, from 240 to 500 years.

Hydration. — While occasionally observed by some investigators, the full significance of hydration, in its application to rock-weathering, has only recently been pointed out. It has long been known, that anhydrite ($CaSO_4$), by the assumption of water (hydration), increases in volume; thereby resulting in uplift, and, it may be, in crumpling and fracturing of the rocks, which overlie it. By comparing analyses of fresh and decayed rock, it will be found, that an increase in water invariably occurs. In rock decomposition, therefore, the assumption of water is one of the main factors; and, if the breaking down is not attended by a loss of constituents, the mass-volume must be proportionally increased. When unaccompanied by a loss in constituents, hydration involves expansion, and thereby becomes a physical agent; while, on the other hand, when accompanied by a loss in constituents, it becomes a chemical agent. As a result of increase in bulk from this cause, certain stresses are induced in rocks, whereby they rapidly crumble, when relieved from pressure and exposed to the air. Branner cites one author,[2] who gives it as his opinion, that some of the hills in Brazil have actually increased in height through hydration. After investigation, Merrill was led to conclude, that the transition of the fresh granitic rock of the District of Columbia into arable soil was accompanied "by an increase in bulk amounting to 88 per cent." Concerning the disintegration of the District rocks, Merrill says:[3] "Granitic rocks in the District of Columbia have been shown [by the author] to have become disintegrated for a depth of many feet with loss of but some 13.46 per cent. of their chemical constituents and with apparently but little change in their form of combination. * * * Aside from its state of disintegration, the newly-formed soil differs from the massive rock mainly, in that its feldspathic and other silicate constituents have undergone a certain amount of hydration."

When we come to the consideration of the special cases of weathering of the various granitic rock-types in Georgia, the results will agree closely, in many instances, with those obtained by Merrill on the District rocks.

[1] Zeit. D. D. Geol. Ges., 1872, bd. XXIV, p. 405.

[2] Bull., Geol. Soc. Amer., 1896, Vol. VII; also, Merrill, Geo. P., Rocks, Rock-Weathering and Soils, 1897, p. 204.

[3] Bull., Geol. Soc. Amer., 1895, Vol. VI, p. 321 *et seq.*

MECHANICAL ACTION OF WATER AND ICE.—Apart from the solvent power of water, it acts, in places, as a powerful erosive agent, in washing away the loose materials, and thereby greatly modifying the surface forms or contours. In the transportation of material by streams, something more than the mere transportation is accomplished. In its journey seaward, the mechanically borne or suspended material becomes a potent agent in the eroding of the stream's bottom and sides. A limit, however, is reached in this work, and the erosion must be reduced to a minimum, when the land-area has been reduced to base-level. Further uplift of the land surface, with reference to the sea-level in the base-leveled region, is necessary, before stream activity can be renewed.

When all the streams, in a given region, have become base-leveled, and the entire surface, reduced to one of moderate relief, approximating the sea-level in elevation through the combined action of stream and other sub-aerial forces, the eroded area is called a pene-plain. The Piedmont plateau of Georgia is a striking example of a pene-plain. The amount of loose material thus removed from a land surface and borne seaward, to be spread out over its floor, is surprisingly great. It has been estimated, that, at the present rate, at which the Mississippi river is wearing down its drainage basin, the American continent would be reduced to sea-level, within four and one-half million years.

Waves exert a powerful action, within a certain zone, on the rocky headlands and cliffs of coast-lines. Dating from the time of Sir A. C. Ramsay, the efficacy of waves as an abrading agent has been dwelt upon by the school of English Geologists, who put forward and developed the idea of planation of land surfaces by marine action. The resulting surface, in contradistinction to "Plains of Sub-aerial Erosion" (pene-plains), are called "Plains of Marine Denudation."[1]

ACTION OF FREEZING WATER AND ICE.—One of the principal mechanical or physical effects of water is that produced by frost action. All rocks are more or less porous, and are, therefore, capable of absorbing a greater or less amount of water. In passing from the liquid to the solid state, water expands with a force equal to about 150 tons to the square foot. One cubic centimeter of water occupies, at 0°C., 1.0908 c.c., in the form of ice, which is equivalent in expansion to about one-tenth of the original volume; and it is rendered a most

[1] Davis, W. M., Bull., Geol. Soc. Amer., 1897; The Geogr. Journal (London), 1895, Vol. 5, pp. 127-146.

potent factor in disintegrating rock. In general, granites may absorb some 0.37 per cent. by weight of water; marble, about 0.30 per cent.; sandstone, varying amounts up to 12 per cent.; and clay, nearly one-fourth of its weight.[1] This water may be, in part, chemically combined; but it is largely interstitial, and hence, is frequently called *quarry water*. For a time after the stone has been quarried, the quarry water dries out; but, when placed in a building, and there exposed to the rains, the rock is likely to absorb more water; and, if in climates of excessive temperature changes, it will work serious result to the rock. All things being equal, a stone, possessing a low absorptive power, such as the average granites, will suffer very much less damage, in a rigid, moist climate, than one, that absorbs a large amount. Apart from this source of water-content in rocks, the water may be present in the different mineral individuals as included water, filling numerous microscopic cavities. This has been known to amount to as much as five per cent. of the whole volume of the mineral in the case of quartz in granite. The passage of the absorbed water from the liquid to the solid state, when sufficiently enclosed, exerts force enough to break or disrupt most rock.

It is self-evident, therefore, that in a climate, where excessive temperature changes are of frequent occurrence, this cause becomes a most disastrous one in the disintegration of the rock. Freezing of the absorbed water is one of the most productive sources of disintegration to stone used in a building. In fact, in latitudes of severe cold, this is the main and all-important agent concerned in breaking down rock-masses. The writer has observed, in some cases,[2] the surfaces of small islands in the arctic region, and along the west coast of North Greenland, to be literally strewn with a heavy covering of rock fragments, of varying sizes, derived from this cause. Sometimes, the covering was of such depth as to entirely obscure the rock in place, over areas of considerable extent.

Any line of weakness present in a rock, such as bedding-planes, microscopic cracks and fractures, water will naturally penetrate; and, upon freezing, it will rend the rock asunder. Some stones are naturally better able to withstand such action than others. All things being equal, a fine-grained and compact rock will absorb less moisture, and will suffer less from this cause, than one, of more open texture. This, however, is not always true; as Merrill has pointed out, that, while an open-textured rock may

[1] Merrill, Geo. P., Rocks, Rock-Weathering and Soils, 1897, pp. 198–199.

[2] Watson, Thomas L., Jour. of Geol., 1897, Vol. V, pp. 14–27.

readily absorb moisture, it will part with it equally as readily; and all the expansive force may not be utilized, in forcing the rock particles apart. As more recently pointed out by Buckley[1] and Van Hise,[2] the percentage of pore-space conditions the extent of injury to a rock, from freezing.

Ice, as a disintegrating agent, manifests itself in still another way; namely, in the form of glacial ice. An ice-cap, similar to the one covering Greenland at present, extended over the entire northern part of the American continent at a recent date, geologically speaking. The record of its scouring and abrading effect upon the rock-surfaces, over which it passed, is replete with the various phenomena accompanying such action. In the Western United States, as well as in the Canadian Rockies, are still found small valley glaciers, with signs of their disintegrating effect upon the rock, wherever they have been studied.

ACTION OF PLANTS AND ANIMALS.—Both plants and animals, to some extent aid in the breaking down of rock-masses, which action is in part physical and in part chemical. While in general these agents are not the principal ones involved in the processes of rock degeneration, they become, at times, quite appreciable and significant as factors in such destruction. The chemical action, resulting from these organic bodies, is mainly that of deoxidation and solution. However slight the action may be, it is oftentimes important. The accumulation of plant remains, through a long period of time, results in the formation of vegetable mould, or humus, which, by the retention of moisture and the leaching out of the organic (humus) acids, promotes chemical decay among the rocks. An important function of plant growth, is the retention of moisture, whereby the rock-surfaces are kept constantly damp, and a continuous solvent action by the water is promoted. Upon decay, the humus acids are taken into solution by the water, and rock decomposition results. Dr. H. Carrington Bolton has shown the decomposing effect of citric acid on 200 different mineral species; and he points out, that this organic acid has a solvent power but slightly less than that of hydrochloric acid.[3] In speaking of the effect of humus acid on hydrated iron sesqui-oxide, Sir A. Geikie says:[4] "This may be observed where pine-trees grow on ferruginous sand, a rootlet one-sixth of an inch in diameter being

[1] Building and Ornamental Stones of Wisconsin, Wis. Geol. & Nat. Hist. Surv., 1898, No. IV, pp. 20–25.

[2] Metamorphism of Rocks and Rock Flowage, Bull., Geol. Soc. Amer., Vol. IX, p. 272.

[3] Proc., Amer. Asso. Adv. Sci., 1883, Vol. XXXI.

[4] Text-Book of Geology, 1893, 3rd Edition, pp. 472–473.

by its decay capable of whitening the sand to a distance of from one to two inches around it."

The physical action, exercised by organic bodies (plants), is principally the result of the force exerted by the insertion of their roots and branches into the cracks and crevices of the rock, resulting in the wedging apart of the rock, and it may be, in the total dislodgment of varying sized fragments from the parent ledges. It sometimes happens, that this action has resulted in a partial detachment of some parts of the masonry from portions of the wall of buildings and other structures.

While plant growth promotes rock degeneration, it also exercises a protective action, as well. Where vegetation is abundant, the erosive action of wind and rain is thereby retarded. This protective influence is well shown, in the reclaiming of lands in portions of France, by the planting of trees on the extensive sand-hills, to prevent further encroachment. Similar protection is afforded by the sage-brush and other forms of plant growth in the sandy tracts of the Western United States. In mountainous districts, avalanches are, in some cases, prevented by plant growth.

In some instances, microscopic organisms, bacteria, have been shown by Schlösing, Müntz[1] and Widograsky to potently aid in the disintegration and decomposition of rock. Bacteria are said by several authors to have been found on various kinds of rocks, such as granites, gneisses, volcanic rocks, schists, limestones and sandstones.

Recently, Mills[2] and Branner[3] have emphasized the important decomposing effects, resulting from the actions of ants in certain localities.

[1] Comptes Rendus de l'Académie des Sciences, 1890, Tome cx, p. 1370.

[2] Amer. Geol., 1889, p. 357.

[3] Bull., Geol. Soc. Amer., 1896, Vol. VII.

PART 2

SPECIAL CONSIDERATION OF THE WEATHERING OF THE GEORGIA GRANITIC ROCKS[1]

Having reviewed the various agencies, by which all fresh rocks are reduced by decay, let us consider now the processes involved in the weathering of the Georgia granitic rocks, and note the changes they have undergone.

Special attention has been given to the weathering of these rocks (the fresh granite and its accompanying residual decay) in both the field and the laboratory. The natural outcrops have been carefully studied in the field, and specimens of the fresh and the weathered rock, representing various stages in the decay, have been collected from the most typical and widely separated localities in the State, and analyzed in the chemical laboratory of the Geological Survey, by the writer. The material is sufficiently representative, and the work, extensive and detailed enough, to arrive at definite conclusions regarding the changes involved in the weathering (transition from the fresh to the decayed rock) of this group of rocks.

Based primarily on texture and structure, three types of granitic rocks are distinguished : (1) the massive, even-granular granites ; (2) the porphyritic granites ; and (3) the banded or foliated granites—gneisses. Laboratory study shows the three types to be nearly identical in mineral and chemical composition. In the field, the porphyritic facies of the granite-masses are found to grade peripherally into an even-granular, medium-coarse textured granite, of the same mineral and chemical composition. Likewise, the gneisses included in this report, have been shown to be the metamorphosed equivalents of the eruptive massive granites, from which they differ, only in a pronounced banded or foliated structure, secondarily induced by metamorphism. For this reason, the gneisses are referred to as granite-gneisses. That comparisons may be effected and emphasis given, whatever differences there may be, arising from the influence of texture on weathering, as illustrated by the degeneration of the Georgia granitic rocks, the rock-decay is treated

[1] Watson, Thomas L., Weathering of the Granitic Rocks of Georgia, Bull., Geol. Soc. Amer., 1901, Vol. XII, pp. 93-108.

separately under (1) granite; (2) porphyritic granite; and (3) granite-gneiss.

The localities described in the following pages are shown on the map facing page 80.

I. Granite

THE OGLESBY BLUE GRANITE AREA

The granites of this area have already been described in Chapter III, pages 213–222. The fresh unaltered granite is a massive, fine-grained rock, dark blue-gray in color, showing an admixture of fine-granular quartz, feldspars and biotite to the unaided eye. The principal minerals are quartz, orthoclase with microperthitic structure, microcline, plagioclase near oligoclase, brown biotite, some muscovite, and a little apatite, zircon and magnetite.

The quartz is frequently intergrown with the feldspar, in the form of rounded ovals or disks of micropegmatitic structure, clearly indicating the contemporaneous growth (crystallization) of the two minerals. It is sometimes enclosed as drop-like inclusions in many of the larger feldspar crystals. The larger individuals further show numerous lines of fracture and undulatory extinction.

The potash feldspars usually show good cleavages; are intergrown with a second feldspar, albite, as microperthite; and are commonly twinned according to the Carlsbad law. The presence of considerable soda in the analyses corroborates the inference, that the feldspar, intergrown with the potash species, is albite. The microcline varies in quantity; but it may equal or even exceed the orthoclase, in a few sections. The plagioclase is inferior, in amount, to the potash feldspars; and, as a rule, it affords low extinction angles in basal sections, indicating an acid feldspar, near oligoclase. This inference is corroborated by the percentage of lime, shown in the analyses. The biotite is deep-brown in color, and strongly pleochroic. It is present, in irregular shreds and elongated plates, with good crystal outlines, and is intimately associated with muscovite, when present. The muscovite varies in quantity, and is always less than the biotite. The remaining microscopic accessories present show the usual characteristic features.

The first decided stage in the weathering of this rock, in which an almost complete change in appearance, from the perfectly fresh granite, is indicated, is represented by a hard, firm, dull-grayish granitic mass, tinged from a faint to a highly ferruginous rusty-brown color. It varies in tenacity, from the firm, hard rock, to material, that readily crumbles, under the gentlest pressure. Aside from change of color and lack of luster in the component minerals, the rock has lost its compact, close-grained texture; and the partially changed granite presents, instead, a somewhat spongy or loose texture in appearance, in which the individual mineral grains are forced slightly apart from each other. The feldspars are of a decidedly white color, perfectly opaque to the naked eye, and have commenced to split along the cleavage-planes. When examined under a pocket-lens, the feldspars show comparatively fresh luster in places; the biotite appears somewhat leached, from hydration and oxidation; and the adjacent areas are slightly discolored, from the hydrous iron sesqui-oxide, derived therefrom. In the center of the biotite plates, the luster on the cleavage faces is as brilliant, and the color, as strong, as that in the fresh rock. Thin sections, made from hand specimens representing this stage in the weathered rock, show a marked yellow color to the naked eye, indicative of the iron sesqui-oxide staining, derived from the decomposition of the biotite.

A microscopic examination of thin sections confirms the above macroscopic description. The feldspars are somewhat cloudy and opaque; but, otherwise, they are comparatively fresh looking. The plagioclase feldspars are more altered, as a rule, than the potash species. The alteration is mostly along the twinning planes in the plagioclase, and mainly along the cleavage lines in the potash feldspars. The only visible change in the quartz is a splitting up along the innumerable fracture-lines, subsequently induced through dynamic action. The quartz and feldspar areas, particularly along the lines of cleavage and breakage, are stained yellow by the hydrous iron sesqui-oxide, derived from the partial decomposition of the biotite.

The biotite appears, in part, perfectly fresh; but a large proportion of this mineral has lost its cleavage and its optical properties, and is replaced by an amorphous, yellow to brown mass, with the surrounding areas partially discolored from the ferruginous constituent. In still other shreds of the biotite, the edges and borders are frayed-out and leached; while the centers remain entirely fresh. As observed in the potash feldspars, alteration also takes place in the biotite, to a marked degree, along the cleavage planes.

No calcite was observed in the thin sections under the microscope; and the further absence of carbonates in the decayed rock was proved, by testing portions of the finely powdered rock in dilute acid.

The weathered rock, yielding the results given in columns 3 and 6, table I, is a light-gray, nearly white, fine-granular granitic sand, showing, to the unaided eye an abundance of quartz, feldspar and biotite. Minute grains of fresh magnetite were separated from the residual sand, by passing a magnet through the incoherent rock-mass. Separation, by washing with water, yielded varying-sized particles of the perfectly fresh silicates. Treatment with cold dilute hydrochloric acid also resulted in a nearly complete separation of the mass into its component minerals. Digestion in very dilute hydrochloric acid, at the temperature of boiling water, showed but slight discoloration from the iron oxide present. This indicates only slight chemical action accompanying the change.

The residue, after cleansing with water, consisted of the finely divided grains of the fresh minerals, quartz, feldspar and biotite. Microscopically, the biotite in the residue gave weaker pleochroism and double-refraction, than did that in the fresh granite, indicative of some alteration. The first visible sign, manifested in the decomposition of this mineral, is a nearly colorless and transparent irregular zone around the edges of the shreds. The feldspar was generally coated with an opaque, dull-white film of supposed kaolin. The percentage of clay in the weathered rock is relatively very small, which further indicates limited decomposition[1] accompanying the change in the rock.

[1] Discrimination is made between the terms *decomposition* and *disintegration*. The former is limited to those changes, which are chemical in their nature; while the latter is restricted to all physical or mechanical forces involved. See Merrill, G. P., Rocks, Rock-Weathering and Soils, 1897, p. 283.

TABLE I

Analyses of Fresh and Decomposed Biotite Granite from the Coggins Quarry, near Oglesby, Elbert County, Georgia

Constituents	Fresh Rock	Decomposed Rock	Partially Decomposed Rock	Recalculated on a Basis of 100			Calculations Based on Decomposed Rock, Column 2			Calculations Based on Partially Decomposed Rock, Column 3			Difference in Loss for Entire Rock	Average Percentage Loss for Entire Rock
							Percentage Loss for Entire Rock	Percentage of Each Constituent Saved	Percentage of Each Constituent Lost	Percentage Loss for Entire Rock	Percentage of Each Constituent Saved	Percentage of Each Constituent Lost		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
SiO_2 . .	69.74	60.94	67.92	69.15	60.38	67.59	33.21	51.97	48.03	5.08	92.65	7.35	28.13	19.145
Al_2O_3 .	16.72	23.29	17.55	16.58	23.08	17.47	2.84	82.87	17.13	0.02	99.88	0.12	2.82	1.430
Fe_2O_3[1]	1.45	2.44	1.53	1.44	2.42	1.52	0.00	100.00	0.00	0.00	100.00	0.00	0.00	0.000
CaO . .	1.93	0.04	0.99	1.91	0.04	0.98	1.88	1.25	98.75	0.98	48.75	51.25	0.90	1.430
MgO . .	0.36	0.43	0.32	0.36	0.42	0.32	0.10	70.00	30.00	0.04	89.48	10.52	0.06	0.070
Na_2O .	4.84	2.18	3.57	4.80	2.16	3.55	3.51	26.79	73.21	1.43	70.15	29.85	2.08	2.470
K_2O . .	5.33	3.57	5.43	5.29	3.54	5.41	3.18	39.86	60.14	0.16	96.95	3.05	3.02	1.670
Ignition	0.47	8.03	3.17	0.47	7.96	3.16	0.00[2]	100.00	0.00[2]	0.00[2]	100.00	0.00[2]	0.00[2]	0.000[2]
Total .	100.84	100.92	100.48	100.00	100.00	100.00	44.72			7.71			37.01	26.215

[1] All iron was estimated as Fe_2O_3. The iron was assumed to be constant. [2] Gain

In columns 1, 2 and 3, of table I, are given the results of analyses of the fresh and partially decayed granite, and in columns 4, 5 and 6, are included the same results, recalculated to a basis of 100. In columns 11 and 12, are the calculated percentage amounts of the various constituents, saved and lost, based on analyses of the fresh and partially decayed rock, in columns 4 and 6.[1]

Assuming the iron oxide to remain constant, we find by calculation: (1) That the residual product has retained 92.65 per cent. of its original SiO_2, and 99.88 per cent. of the Al_2O_3; and that it has retained all the Fe_2O_3; 48.75 per cent. of the CaO; 89.48 per cent. of the MgO; 70.15 per cent. of the Na_2O; and 96.95 per cent. of the K_2O. (2) That there has been a total loss for the entire rock, of only 7.71 per cent., as indicated in column 10, in the transition from fresh rock to the residual product—partially decomposed rock, as represented in columns 3 and 6. It will be observed, that the greatest loss is in the lime and soda salts, which are in combination in the fresh rock, in the form of soda-lime feldspar—plagioclase. This is natural, and in accord with the results of other workers; since, given the same conditions, the plagioclases are more susceptible to change than the potash species; and, hence, they yield more readily to the action of the atmospheric agents.

It is evident, that the fresh granite, in this particular case, has been disaggregated and reduced to a fine-grained granitic sand, mainly through physical forces, accompanied by only slight chemical change. That is to say, that, through hydration and temperature changes, the individual minerals have crumbled along the lines of natural parting and weakness (the cleavage and twinning planes, in the case of the feldspars and biotite, and the lines of fracture due to dynamo-metamorphism, in the case of the quartz), aided by some chemical change. The feldspars have yielded more readily, than the biotite. The alteration products remaining, as shown under the microscope, are kaolin, hydrous iron sesqui-oxide, and some muscovite. The above is more characteristic of the preliminary stages in granitic weathering, and is essentially analogous to the weathering of the granites of the District of Columbia, described by Dr. Merrill.[2]

We pass next to a more advanced stage in the decay of the same rock, in which the process has been largely one of decomposition.

[1] The formula employed in these calculations is as follows: $\frac{A}{B \times C} = x$; and $100 - x = y$, in which A = the percentage of any constituent in the residual material; B = the percentage of the same constituent in the fresh rock; and C = the quotient obtained by dividing the percentage amount of alumina (or iron sesqui-oxide, whichever is taken as a constant factor) of the residual material, by that, in the fresh rock, the final quotient being multiplied by 100. x then equals the percentage of the original constituent saved, in the residue, and y, the percentage of the same constituent lost. Merrill, Geo. P., Rocks, Rock-Weathering and Soils, 1897, p. 210.

[2] Bulletin, Geol. Soc. Amer., 1895, Vol. VI, pp. 321-332; also, Rocks, Rock-Weathering and Soils, 1897, pp. 206-213.

The material, yielding the results given in columns 2 and 5, table I, was a bright-red, ferruginous clay, which, upon close examination, revealed small light-colored specks of quartz and kaolinized feldspar, with brass-colored mica folia distributed through the clayey mass. Viewed from a slight distance away, the material appears as a homogeneous, highly colored, ferruginous clay. Upon treatment with water, the clayey mass was resolved into a deep bright-red powder, through which were disseminated the brass-colored mica shreds. After renewed digestion in very dilute hydrochloric acid, at the temperature of boiling water, and the residue, cleansed, a perfectly white mass of fine sandy material, in which no biotite could be distinguished, was left. Under the microscope, however, abundant quartz grains and nearly completely kaolinized feldspars were recognizable. The first decanted liquids were of a deep wine-red color, due to the soluble iron oxide in the clay. A second portion of the decayed rock was treated in the same way, for half-a-day, and the residue was cleansed and examined microscopically, with the same result; namely, that not a trace of the biotite was visible. Numerous magnetite grains, just as fresh, apparently, as in the unaltered granite, were distributed through the residue. A few of the brass-colored mica folia were separated from the clay, and treated in hot and cold dilute hydrochloric acid, respectively, and were found to be slowly soluble in each. The leached biotite shreds were exceedingly brittle, and fell to pieces, under slight pressure. When thoroughly agitated in water, and the silt and clay was decanted off, the remaining ferruginous, granular mass consisted of fresh-looking grains of quartz and some feldspar, through which were distributed leached mica shreds. Small and irregular grains of fresh magnetite were separated from the clay-product, by means of the magnet. No calcite or other carbonates were present in the residual clay.

Passing now to the calculated amounts of the individual constituents, saved and lost, in columns 8 and 9, it will be observed, that of the original constituents in column 4, only 51.97 per cent. of the SiO_2; 82.87 per cent. of the Al_2O_3; all the Fe_2O_3; 1.25 per cent. of the CaO; 70.00 per cent. of the MgO; 26.79 per cent. of the Na_2O; and 39.86 per cent. of the K_2O have been saved, in passing from the fresh to the decomposed rock. Here, as in the above case, there has been a large increase in water. The change has been accompanied by a total loss, for the entire rock, of 44.72 per cent., shown in column 7 of the table, distributed between the SiO_2, Al_2O_3, CaO and the alkalies.

In the former case, where the early stages in the granitic weathering was accomplished mainly through physical forces resulting,

GULLIED SURFACE IN RESIDUAL CLAY, DERIVED FROM BIOTITE GRANITE, NEAR ATLANTA, GEORGIA.

frequently, in reducing the fresh granite to a loose feldspathic sand, a total loss for the entire rock, of only 7.71 per cent., resulted. In the latter case, the process has been continued and the weathering is far advanced. The chemical forces have become the most active, and the residual product is a highly ferruginous, gritty clay, in which the transition from the fresh to the decayed rock has resulted in a total loss, for the entire rock, of 42.37 per cent. A difference of 34.66 per cent. is thus shown in the total loss for the two stages of the same rock. In the advanced stage of decay, the action has been principally one of hydration, oxidation and solution, in which the bulk of the more soluble constituents has been removed.

A weighed portion of the finely powdered fresh granite, digested in 100 c.c. of half-normal hydrochloric acid, for three hours, at the temperature of boiling water, yielded 10.56 per cent. of soluble matter. A partial analysis of the extract gave:—

$Al_2O_3.Fe_2O_3$	4.05
CaO	0.53
MgO	trace
Na_2O	0.57
K_2O	1.07
Total	6.22

THE LEXINGTON BLUE GRANITE AREA

The Lexington blue granite area is the prolongation, to the south-west into Oglethorpe county, of the Oglesby area described above. The rock is remarkably uniform in color and texture, and in mineral and chemical composition, over the entire area. The manner and character of weathering in the field is identical for the two sections.

The results, given in table II, are analyses of the fresh and partially weathered rock from the Lexington Blue Granite quarry, near Lexington, Georgia. The Lexington granite is only distinguishable from that of the Oglesby area, in being a shade lighter in color. Thin sections of the two granites show the same minerals, both essential and accessory, in nearly the same proportions.

The partially weathered granite, an analysis of which is given in column 2, table II, is hard and moderately firm rock, light gray in color, and slightly stained a yellowish-brown. It consists of opaque and partially kaolinized feldspars and quartz and black biotite. The last named mineral appears in a state of incipient alteration, manifested in the slight staining of the adjacent lighter-colored feldspar and quartz areas by the liberated ferruginous constituent. The rock is somewhat loose and porous in texture, and crumbles to a medium-grained sand, on the corners and edges. It is similar in every respect to specimens representing the first stages in weathering, of the Oglesby blue granite, described above.

A thin section of the decayed rock indicated considerable change in the feldspars and biotite, under the microscope. The feldspars were dark and cloudy from kaolinization, and the biotite was altered to a dark and light yellowish-brown color, without pleochroism and double-refraction. Staining of the surrounding lighter-colored areas of quartz and feldspar, from the ferruginous constituent of the biotite, was very noticeable under the microscope. Only occasional shreds of biotite presented anything like a fresh appearance. As a result of physical forces, the individual quartz anhedra were beginning to divide and separate into smaller particles along the numerous fracture lines.

TABLE II

Analyses of Fresh and Partially Decomposed Biotite Granite, from the Lexington Blue Granite Company's Quarry, near Lexington, Oglethorpe County, Georgia

Constituents	Fresh Rock	Partially Decayed Rock	Recalculated to a Basis of 100		Percentage Loss for Entire Rock	Percentage of Each Constituent Saved	Percentage of Each Constituent Lost
	1	2	3	4	5	6	7
SiO_2	70.03	70.50	69.37	70.32	9.21	86.71	13.29
Al_2O_3	15.62	16.84	15.47	16.80	1.09	92.92	7.08
Fe_2O_3 [1]	1.31	1.53	1.30	1.52	0.00	100.00	0.00
CaO	2.45	1.15	2.43	1.15	1.45	40.49	59.51
MgO	0.52	0.18	0.52	0.18	0.36	30.00	70.00
Na_2O	4.82	4.47	4.77	4.46	0.95	80.07	19.93
K_2O	5.42	4.52	5.37	4.51	1.50	71.92	28.08
Ignition	0.77	1.06	0.77	1.06	0.00	100.00	00.00
Total	100.94	100.25	100.00	100.00	14.56		

[1] All iron was estimated as Fe_2O_3. The iron is assumed to be constant.

In columns 1 and 2 of table II, are given the results of analyses of the fresh and partially decayed rock; and, in columns 3 and 4, the results are recalculated to a basis of 100. In columns 6 and 7, are given the calculated percentage amounts of the various constituents, saved and lost, as before.

The special features, to which attention need here be called, are: (1) That 14.56 per cent. of the original matter has been lost, in the transition from fresh to partially decayed rock, as indicated in column 5. (2) That 86.71 per cent. of the original SiO_2; 92.92 per cent. of the Al_2O_3; all the Fe_2O_3; 40.49 per cent. of the CaO;

30.00 per cent. of the MgO; 80.07 per cent. of the Na_2O; 71.92 per cent. of the K_2O remain. (3) That the total amount of water, as indicated by the ignition, has increased.

The percentage amounts, saved and lost, of the various constituents, are observed to be in approximately the same proportions, as for the similar stage of decay in the Oglesby rock, represented in table I. The total percentage loss for the entire rock, in the case of the Lexington granite (14.56), is somewhat greater than for the Oglesby granite (7.71). The two are in every respect analogous, however, and represent the earlier stages in the process of granitic weathering.

A weighed portion of the finely powdered fresh rock, from the Diamond Blue Granite Company's quarry, a few miles west of the Lexington quarry, but of the same granite, when treated with 100 c.c. of boiling half-normal hydrochloric acid, yielded 9.77 per cent. of soluble matter. A partial analysis of the extract gave:—

$Al_2O_3.Fe_2O_3$	4.23
CaO	0.54
MgO	trace
Na_2O	0.64
K_2O	1.09
Total	6.50

When compared with similar results obtained from the Oglesby granite, it will be noticed, that the percentage of soluble matter and the percentage composition of the extracts are very close.

THE LIGHT-GRAY GRANITE, FROM THE SWIFT & WILCOX QUARRY NEAR ELBERTON

The rock from this quarry was selected as representative of the belt of medium light-gray granite lying east of, but adjacent and roughly parallel to, the Oglesby-Lexington blue granite area. It differs from the blue granite only in being of lighter color and coarser grain. The biotite is present in larger and stouter plates, in the former rock. The two belts are remarkably similar, in mineral and chemical composition. At several places near the line of contact, they apparently grade into each other; but they are well differentiated in color and texture, in the extreme portions of the two belts.

Under the microscope, thin sections of the fresh gray granite show quartz; the potash feldspars, orthoclase and microcline with considerable microperthitic structure; soda-lime feldspar, near oligoclase; and biotite, with some intergrown foils of muscovite. Prismatic inclusions of apatite and zircon, and a few scattered grains of magnetite, are present. Chlorite and epidote occur as secondary products, from the alteration of the feldspars and biotite. The potash feldspars usually show marked cleavages parallel to P and M; and twinning is common among all the feldspar species.

The partially decayed granite, yielding the analysis in column 2, table III, was collected from an incoherent mass of coarse-grained granitic sand, several feet below the surface. The rock had a pronounced yellowish cast, and the principal minerals, quartz, feldspar and biotite, were in a moderately fresh condition to the naked eye. The disintegration was sufficiently advanced, however, to admit of the separation of the magnetite grains from the other minerals, by means of the magnet. The amount of clay is exceedingly small in the decayed rock, and does not exceed three per cent. at the greatest. The biotite folia were almost entirely fresh; and, aside from a slight discoloration and some kaolinization of the feldspars, the quartz and feldspars were equally as fresh looking.

A microscopic examination of some half-dozen thin sections of the still hard and firm, though dull-looking and partially discolored rock, from various places over the belt, showed considerable alteration in the feldspars and biotite. The feldspars were covered, as a rule, with small patches of kaolin, and some irregular shreds and scales of muscovite. The alteration in the feldspars had progressed mainly along the twinning and cleavage planes. The biotite was altered to an opaque, light to dark-brown mass, without trace of cleavage or optical properties of the original mineral shown. In many cases, the ferruginous constituent of the biotite had been partially liberated, as was shown in the discoloration of the adjacent lighter-colored mineral areas. The quartz and some of the feldspars were crossed by lines of fracture, resulting from mechanical strain; and, in the weathered product, the individual crystals of the two minerals were beginning to stand apart and separate into smaller fragments. This rock represents apparently the same stage of decay as the sand.

TABLE III

Analyses of Fresh and Partially Decomposed Biotite Granite, from the Swift and Wilcox Quarry, near Elberton, Elbert County, Georgia

Constituents	Fresh Rock	Partially Decayed Rock	Recalculated to a Basis of 100		Percentage Loss for Entire Rock	Percentage of Each Constituent Saved	Percentage of Each Constituent Lost	Soil 2 Feet Below Surface
	1	2	3	4	5	6	7	8
SiO_2	69.45	69.00	70.12	69.17	5.47	92.20	7.80	73.90
Al_2O_3 [1]	15.93	17.31	16.08	17.35	0.00	100.00	0.00	13.78
Fe_2O_3 [2]	1.31	1.31	1.32	1.32	0.08	93.61	6.39	1.23
CaO	1.91	1.18	1.93	1.18	0.82	57.28	42.72	0.53
MgO	0.55	0.42	0.56	0.42	0.16	71.18	28.82	0.05
Na_2O	4.33	4.00	4.37	4.01	0.62	85.86	14.14	2.92
K_2O	5.16	4.74	5.21	4.75	0.77	85.27	14.73	5.43
Ignition	0.40	1.79	0.41	1.80	0.00	100.00	00.00	2.60
Total	99.04	99.75	100.00	100.00	7.92			100.44

[1] The alumina is assumed to be constant. [2] All iron was estimated as Fe_2O_3.

Recalculating the analyses of the fresh and partially decayed rock, in columns 1 and 2, to a basis of 100, and calculating the percentage amounts, saved and lost, of each constituent, on an assumed Al_2O_3 constant basis, we find that 92.20 per cent. of the original SiO_2; all the Al_2O_3; 93.61 per cent. of the Fe_2O_3; 57.28 per cent. of the CaO; 71.18 per cent. of the MgO; 85.86 per cent. of the Na_2O; and 85.27 per cent. of the K_2O have been saved. The change from fresh to partially decayed rock has been accompanied by a total loss of only 7.92 per cent., as is indicated in column 5.

Weighed portions of the finely powdered fresh granite, from the Swift & Wilcox quarry, and from Echols Mill in Oglethorpe county, respectively, digested for three hours in 100 c.c. of boiling half-normal hydrochloric acid, yielded 9.20 and 8.37 per cent. of soluble matter. A partial analysis of the extracts gave:—

	Swift & Wilcox	Echols Mill
Al_2O_3, Fe_2O_3	3.69	2.75
CaO	0 26	0.93
MgO	trace	trace
Na_2O	0.29	0.30
K_2O	1.02	0.99
Total	5 26	4.97

It is evident, from these data, that the Elberton gray granite, a the surface, has been reduced to a coarse sand, in which all the component minerals are readily recognizable, through the action of physical forces, accompanied by only very slight chemical change. The process has been mainly one of disintegration, rather than of decomposition.

In column 8, of table III, is given an analysis of the earth, that covers the granite on the upper side of the quarry to a depth of several feet. The sample was taken at a depth of from one to one and a half feet from the surface, and was not entirely free from organic matter. It is a finely pulverulent, highly siliceous, medium-colored, loamy soil, through which are scattered occasional mica shreds. No reliable calculations can be made from this analysis, since it is not entirely free from foreign impurities. It is introduced merely for comparison.

THE COWETA-MERIWETHER COUNTIES DARK BLUE-GRAY GRANITE AREA

In color and texture, and in mineral and chemical composition as well, the dark-colored granites of Coweta and Meriwether counties are quite similar to those of the Oglesby-Lexington area described above. Hand specimens of the granite, from parts of the different areas, can hardly be distinguished from each other. The two areas, as seen from the map, are in widely separated sections of the State. The appearance of the decayed rock and the character of weathering in the field, for the two areas, however, are strikingly alike. The granite is exposed in boulder and ledge forms, and the residual (weathered rock) varies from a highly ferruginous, stiff, red, gritty clay, to a moderately fine-grained, light-gray granitic sand, in which the individual minerals appear in a fairly fresh condition.

THE R. D. COLE QUARRY, NEAR NEWNAN, COWETA COUNTY.— The granite decay is plainly visible in the quarry-opening, to a depth of 15 feet. The first five feet from the surface, is a stiff red clay, decidedly gritty from the presence of free quartz grains and undecomposed silicates, through which are distributed leached brass-colored mica folia. From this point downward, the weathering has progressed along invisible, roughly parallel parting planes in the fresh granite, dividing the rock into sheets of varying thickness. Nearest the planes, where free circulation of water and oxygen takes place, the granite is broken down into a bright-red, gritty, partially clayey product. In the center of the sheets, the rock, as a rule, is moderately fresh and firm, but somewhat discolored. Below this zone, the rock is perfectly hard, fresh, massive granite, of a superior quality.

The fresh granite is dark-gray in color, and medium fine-grained, massive in texture. It is a biotite granite, closely resembling the Oglesby blue granite, in the hand specimens. Microscopically, the component minerals are quartz, orthoclase with microperthitic intergrowths of a second feldspar (albite), microcline, plagioclase near oligoclase, biotite, a little muscovite, apatite, zircon and magnetite. The biotite is much altered to chlorite and epidote. The epidote is very abundant, as large grains with well defined crystal boundaries. The comparatively large amount of this mineral in the Cole granite is shown in the large percentage of lime in the analysis. Some secondary muscovite is present, derived from the feldspathic alteration. Microscopic examination of a thin section of the partially weathered granite, indicates, besides the alteration to chlorite and epidote, further chemical change in the biotite, shown in the discoloration of the lighter-colored areas from the hydrous iron sesqui-oxide. Consequently, the mica folia are reduced, as a rule, to yellowish-brown shreds. The feldspars are, in some cases, cloudy and opaque through kaolinization; while, in others, they are apparently fresh and unchanged.

The chemical analysis, given in column 2, of table IV, is of specimens of the partially weathered granite, taken 10 feet below the surface. The material was a light-gray, chalky-looking, moderately firm rock, readily crumbling under pressure, into a fine-grained sand, in which the black biotite folia are visible. When seen under a pocket-lens, the feldspars are white and opaque from kaolinization, with the biotite hardly indicating more than an incipient alteration around the edges.

In column 3, is an analysis of the decomposed granite, taken five feet below the surface. This product is a deep red clay, which, owing mainly to the presence of free quartz and some of the undecomposed silicates, has a distinct gritty feeling. Upon separating the silt and clay from the coarser particles, by washing, an abundance of the biotite, fresh quartz and kaolinized feldspars are left as a residuary sand. The biotite is in various stages of decay, varying from the thoroughly leached brass-color to black, partially altered folia. The largest grains of the partially decayed minerals, of the residual sand, measure 2.5—3 mm. in diameter; while the bulk of these fall within the range of one millimeter. They vary, from this size down to the smallest silt and clay particles—0.1—0.005 mm. Removal of the iron sesqui-oxide staining from the clayey product by renewed digestions in hot dilute hydrochloric acid, showed a large proportion of fresh grains of biotite, feldspar and quartz, with sharp, angular borders.

TABLE IV

Analyses of Fresh and Decomposed Biotite Granite, from the R. D. Cole Quarry, near Newnan, Coweta County, Georgia

Constituents	Fresh Rock	Partially Weathered Rock, 10 Feet Below Surface	Decomposed Rock, 5 Feet Below Surface	Recalculated to a Basis of 100			Percentage Loss for Entire Rock	Percentage of Each Constituent Saved	Percentage of Each Constituent Lost
	1	2	3	4	5	6	7	8	9
SiO_2 . . .	69.08	61.18	56.99	68.75	61.18	57.04	30.21	56.05	43.95
Al_2O_3 [1] .	17.67	22.80	26.02	17.59	22.80	26.04	0.00	100.00	0.00
Fe_2O_3 [2] .	1.41	1.74	1.91	1.40	1.74	1.91	0.10	92.27	7.73
CaO . . .	3.27	3.06	0.75	3.25	3.06	0.75	2.74	15.59	84.41
MgO . . .	0.64	0.34	0.17	0.64	0.34	0.17	0.52	18.08	81.92
Na_2O . .	4.56	7.94[3]	1.91	4.54	7.94[3]	1.91	3.24	28.46	71.54
K_2O . . .	3.29		2.40	3.27		2.41	1.64	49.89	50.11
Ignition .	0.56	2.94	9.76	0.56	2.94	9.77	0.00	100.00[4]	0.00
Total . .	100.48	100.00	99.91	100.00	100.00	100.00	38.45		

[1] The alumina was assumed to be constant. [2] All iron was estimated as Fe_2O_3. [3] Calculated by difference. [4] Gain.

Recalculated as before, the analyses give the results shown in columns 7, 8 and 9, table IV. A comparison of the figures in columns 1 and 7 shows a total loss of material equal to 38.45 per cent., accompanied by the usual gain in water. Of the individual constituents, 43.95 per cent. of the SiO_2; 7.73 per cent. of the Fe_2O_3; 84.41 per cent. of the CaO; 81.92 per cent. of the MgO; 71.54 per cent. of the Na_2O; and 50.11 per cent. of the K_2O have disappeared, in the transition from fresh to decayed rock. It will be observed, that, with the exception of the Al_2O_3 and Fe_2O_3, there has been a greater loss in each of the individual constituents. Attention is called to the greater loss in the potash than in the soda. The very slight loss in iron oxide would seem to indicate, that decomposition took place in the supply of oxygen sufficient to convert this constituent into the insoluble sesqui-oxide, and the most of it was retained.

Here, as in the case of the Oglesby granite, described above, the decay has advanced beyond the preliminary stages of granitic weathering, and the process has become largely one of decomposition, rather than disintegration. The change from fresh to decayed rock has been accompanied by a loss of approximately two-fifths of the original material.

THE GREENVILLE GRANITE COMPANY'S QUARRY, NEAR GREENVILLE, MERIWETHER COUNTY.—The fresh, unaltered rock is a medium-massive grained, dark blue-gray granite, showing, in the hand specimen, in addition to the quartz, feldspar and biotite, scattered shreds of muscovite.

Thin sections of the rock show the component minerals to be quartz, microperthitic orthoclase, microcline, plagioclase near oligoclase, biotite, a little muscovite, some apatite and zircon, and fine thread-like inclusions of rutile in the quartz anhedra. The potash feldspars predominate. They show good cleavages, as a rule, and are commonly twinned according to the Carlsbad law. The orthoclase, more particularly, is intergrown with a second feldspar, albite, as microperthite. Single plagioclase crystals are only sparingly present, and are idiomorphic in crystal outline. Biotite is uniformly distributed through the rock. It is deep-brown in color; has strong absorption; and is altered in part to chlorite.

The specimens for analysis were collected from a 35-foot vertical section along the quarry face. At the bottom, the granite is hard, compact and fresh, and without a trace of decomposition products. The decayed rock extends to an approximate depth of 20 feet in the quarry. The bottom portion of the 20-foot zone is partially altered rock, grading into the fresh granite below. The first 10 to 15 feet from the surface is a highly ferruginous, deep-red clay, distinctly gritty in feeling, when rubbed between the hands, owing to the presence of free quartz and some partially undecomposed silicates. The deep-red plastic clay nearest the top has abundant completely leached biotite folia, of a brass-color, distributed through it. The decayed mica folia are conspicuously present in the surface portions of the entire belt of residual clay derived from the blue granite, and is best seen after rains, when the surface clays (soil) have a distinct yellow cast imparted to them by the abundance of the brass-colored biotite plates. The leached folia are very brittle, and readily crumble under the gentlest pressure. They are easily soluble in dilute acid. The gradation then, is from a dark-red, highly plastic, gritty clay, through a lighter and brighter red clay, into a slightly reddish to gray, fairly firm rock. When washed with water, and the clay is separated from the mass, the residue is deep-red and composed of a sandy aggregate of quartz, partially kaolinized feldspar and leached (brass-colored) mica shreds. When passed through an 80-mesh sieve, and the product is treated with dilute acid to remove the iron stain, fresh looking granules of quartz, feldspar and mica, with sharp, angular outlines, remain. Approximately one-fourth of the quartz grains were retained in the sieve.

The bulk of the material remaining in the sieve was quartz, with a sprinkling of feldspar and mica. An unusually large percentage of the residual product is clay. When washed with water and further cleansed with dilute acid, particles of quartz, feldspar, mica, magnetite, and some zircon were recognized. The magnetite was separated from the other minerals by means of the magnet. The largest quartz grains measure several millimeters in diameter; while the bulk of the mineral grains are considerably under one millimeter.

The proportion of clay to partially decomposed minerals, in the sample collected 10 feet below the surface, a chemical analysis of which is shown in column 2, table V, is approximately the same as for the one taken five and a half feet below the surface. The two clays differ principally in color. The one nearest the top is a homogeneous dark-red clay. The other, taken 10 feet below the surface, is a partially red-and-white mottled clay, and much lighter in color. The coloring matter, iron sesqui-oxide, has not become so uniformly diffused through the mass, as in the surface portion.

The neighboring hill-sides are mantled to a considerable depth, by a covering of the dark-red clay, derived from the decay of the underlying granite. Their surfaces have been deeply trenched and furrowed by the rains, until a depth of 50 feet is reached in some cases. In no case, however, have the gullies cut through to the fresh rock beneath; they are confined within the limits of the red clay. This form of erosion is so pronounced, in places just beyond the northern limits of Greenville, that the land surface bears a striking resemblance in miniature to the western type of "bad-lands" topography.[1]

[1] See Plate II, Fig. 2.

TABLE V

Analyses of Fresh and Decomposed Biotite Granite from the Greenville Granite Company's Quarry Greenville, Meriwether County, Georgia

Constituents	Fresh Rock	Decomposed Rock, 10 Feet below Surface	Decomposed Rock, 5½ Feet below Surface	Recalculated on a Basis of 100			Calculations Based on Decomposed Rock, 5½ Feet below Surface			Calculations Based on Decomposed Rock, 10 Feet below Surface			Difference in Loss for Entire Rock	Average Percentage Loss for Entire Rock
							Percentage Loss for Entire Rock	Percentage of Each Constituent Saved	Percentage of Each Constituent Lost	Percentage Loss for Entire Rock	Percentage of Each Constituent Saved	Percentage of Each Constituent Lost		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
SiO_2 . .	69.88	54.57	51.29	69.28	54.25	51.03	53.48	22.80	77.20	46.50	32.77	67.23	6.98	50.025
Al_2O_3 .	16.42	25 90	29.69	16.28	25.75	29.54	7.13	56.18	43.82	5.57	66.21	33.79	1.56	6.315
Fe_2O_3[1]	1.96	4.69	6.33	1.95	4.66	6.30	0.00	100.00	0.00	0.00	100.00	0.00	0.00	0.000
CaO . .	1.78	0.05	0.07	1.77	0.05	0.07	1.74	1.22	98.78	1.74	1.18	98.82	0.00	1.740
MgO . .	0.36	0.21	0.14	0.36	0.21	0.14	0.31	12.06	87.94	0.27	24.41	75.59	0.04	0.290
Na_2O .	4.46	2.16	1.12	4.42	2.15	1.12	4.07	7.84	92.16	3.51	20.39	79.61	0.56	3.790
K_2O . .	5.63	2.87	1.50	5.58	2.85	1.49	5.11	8.25	91.75	4.39	21.38	78.62	0.72	4.750
Ignition	0.36	10.14	10.36	0.36	10.08	10.31	0.00	100.00[2]	0.00	0.00	100.00[2]	0.00	0.00	0.000
Total .	100.85	100.59	100.50	100.00	100.00	100.00	71.84			61.98			9.86	66.910

[1] All iron was estimated as F_2O_3. The iron is assumed to be constant.

[2] Gain.

Recalculated as before, the analyses give the results shown in columns 7, 8 and 9, for the dark-red residual clay, taken five and a half feet below the surface. In the same way, calculations, based on the decomposed rock 10 feet below the surface, show the percentage amounts, saved and lost, in columns 11 and 12; also, the total loss for the entire rock in column 10.

Assuming the Fe_2O_3 to remain constant, calculations, based on the fresh and derived product, five and a half feet from the surface, indicate, that 77.20 per cent. of the SiO_2; 43.82 per cent. of the Al_2O_3; 98.78 per cent. of the CaO; 87.94 per cent. of the MgO; 92.16 per cent. of the Na_2O; 91.75 per cent. of the K_2O have disappeared. Likewise, the change from fresh rock to the similar product, occurring 10 feet below the surface, shows that 67.23 per cent. of the SiO_2; 33.79 per cent. of the Al_2O_3; 98.82 per cent. of the CaO; 75.59 per cent. of the MgO; 79.61 per cent. of the Na_2O; 78.62 per cent. of the K_2O have been lost. In each case, the change has been accompanied, as would be expected, by a large gain in water; and the total loss for the entire rock is equivalent to 71.84 and 61.98 per cent., respectively, for the two stages of decayed rock, thus showing a difference between the two, of 9.86 per cent.

It will be observed, from the figures, that the loss in constituents is proportional to the depth; and, while larger than for other similar acid igneous rocks, the removal of the soluble constituents has been in the usual normal ratios. The iron content has all been retained, as the result of oxidation in a sufficient supply of oxygen. A greater loss in the lime than in the magnesia, and in the soda than in the potash has resulted, in each case. The loss in these constituents (the alkalies and alkaline earths), however, is nearly equal. The unusually large total loss for the entire rock, less than three-fourths, in its transformation from fresh granite to residual clay, indicates, that the process has nearly reached completion, and is mostly one of decomposition. The very small percentage of the soluble minerals, feldspar and mica, of the fresh rock, left in the clay, fully confirms the analytical results.

With the single exception of a biotite-gneiss, from Albemarle county, Virginia, described by Merrill,[1] work on the weathering of acid igneous rocks has, hitherto, been confined to residual products, derived from the fresh rock, during the early stages of weathering; and the processes involved have been largely those of disintegration (physical), rather than decomposition (chemical). In the above case, the residual material roughly approximates an

[1] Bull., Geol. Soc. Amer., 1897, Vol. VIII, pp. 157–168. Also, Rocks, Rock-Weathering and Soils, 1897, pp. 213–215.

almost pure ferruginous clay, in which chemical forces have been most actively engaged in the processes of rock-decay. The weathered rock, found nearest the fresh granite in the quarry, is being reduced mainly through the physical forces, hydration and temperature changes.

It is apparent, therefore, from the above, that the early stages in weathering of the Georgia granites are chiefly physical in nature, which, as shown in many of the areas in the State, frequently results in reducing the rock to a granitic sand, accompanied by only slight chemical change. Careful examination of exposures of the weathered granite in the field invariably shows a loose textured, partially friable, though moderately firm, rock, which readily crumbles on the corners and edges into a light-gray sand, the feldspar of which, as a rule, is the only mineral manifesting visible chemical change. It is, by no means exceptional, however, to find this stage in the weathering of the rocks accompanied by chemical change in the mica, being equally pronounced, and frequently more advanced, than in the feldspar.

The forces involved, however, in producing a complete change in the rock, as a geologic unit, are chemical; and they are accordingly most complete in the more advanced stages of the degeneration—weathering. That is to say, in the early stages of the process, the physical agents predominate; while the chemical forces are the most active, in the advanced stages.

II. Porphyritic Granite

Three of the largest and most typical porphyritic granite areas have been selected, for indicating the processes involved in the weathering of this type of rock in the State. Two of the areas represent the massive porphyritic granite; while the third is a pronounced foliated type of the same rock.

THE HEGGIE-ROCK, NEAR APPLING, COLUMBIA COUNTY

The Heggie-rock is a flat, doming porphyritic granite mass containing nearly 75 acres in the exposure, and is located three miles east of Appling, the county-seat. It grades interiorly, from a true porphyritic into a non-porphyritic, medium-coarse granite facies near the periphery. The rock is massive over the entire exposure, without visible indications of either fluxion, or secondary banded, structure. When fresh and unaltered, the rock is composed of a coarse-grained ground-mass, of dark vitreous quartz, flesh-colored feldspars and black biotite, containing embedded feldspar phenocrysts, 30 to 40 mm. long, and 5 to 15 mm. broad;

usually tabular, parallel to the clinopinacoid (010), and commonly twinned according to the Carlsbad law. The cleavages parallel to the base (001) and the clinopinacoid (010) are very pronounced.

A thin section of one of the phenocrysts showed the characteristic microcline structure under the microscope. It contained inclusions of all the ground-mass minerals, without definite arrangement or orientation shown in them. Orthoclase also occurs porphyritically developed. A chemical analysis of carefully selected fragments of phenocrysts from this rock gave the writer the folling results:—

Silica, SiO_2	64.64
Alumina, Al_2O_3	19.64
Iron Sesqui-oxide, Fe_2O_3	0.37
Lime, CaO	0.67
Magnesia, MgO	trace
Soda, Na_2O	3.06
Potash, K_2O	10.00
Ignition	0.22
Total	98.60

Sp. G. —— 2.60 (Thoulet solution).

The porphyritic crystals make up nearly half of the total rock-mass. Feldspar, including orthoclase, microcline and plagioclase, is greatly in excess of any single mineral constituent present.

TABLE VI

Analyses of Fresh and Partially Decomposed Biotite Porphyritic Granite, from the Heggie Rock, near Appling, Columbia County, Georgia

Constituents	Fresh Rock	Partially Decomposed Rock	Recalculated on a Basis of 100		Percentage Loss for Entire Rock	Percentage of Each Constituent Saved	Percentage of Each Constituent Lost
	1	2	3	4	5	6	7
SiO_2	69.77	67.87	69.69	67.60	12.74	81.72	18.28
Al_2O_3	17.05	18.08	17.03	18.01	1.85	89.11	10.89
Fe_2O_3[1]	1.60	1.91	1.60	1.90	0.00	100.00	0.00
CaO	2.21	2.28	2.21	2.27	0.30	86.64	13.36
MgO	0.99	0.79	0.99	0.79	0.32	67.23	32.67
Na_2O	3.97	4.32	3.97	4.30	0.35	91.25	8.75
K_2O	4.08	4.52	4.07	4.50	0.28	93.16	6.84
Ignition	0.44	0.63	0.44	0.63	0.00	100.00[2]	0.00
Total	100.11	100.40	100.00	100.00	15.84		

[1] Total iron, estimated as Fe_2O_3. The iron oxide is assumed to be constant. [2] Gain.

In columns 1 and 2, table VI, analyses of the fresh and partially decomposed rock are given. Recalculating these to a basis of 100, and assuming the iron oxide to remain constant, the percentage amounts of each constituent, saved and lost, are shown in columns 5 and 6. The principal features, to which attention need here be called, are as follows: —

(1) Only a slight gain in water is shown in the ignition.

(2) The change from fresh to partially weathered rock has been accompanied by a total loss, for the entire rock, of only 15.84 per cent.

(3) That, of the original constituents, 81.72 per cent. of the SiO_2; 89.11 per cent. of the Al_2O_3; all the Fe_2O_3; 86.64 per cent. of the CaO; 67.23 per cent. of the MgO; 91.25 per cent. of the Na_2O; and 93.16 per cent. of the K_2O, have been saved.

The partially weathered product, yielding these results, was but slightly discolored from the hydration and oxidation of the iron constituent. It was moderately firm rock, crumbling into a coarse, granitic sand under pressure. The feldspars were dull in appearance, cloudy and opaque from kaolinization; while the biotite was almost entirely fresh.

While the change, from fresh to partially weathered rock, is accompanied by only a slight increase in water (hydration) the total loss for the entire rock indicates some chemical action, which has resulted in the removal of a part of the more soluble constituents. In decay, the rock has not progressed beyond the stages of early weathering, and the agencies involved have been mainly physical, aided, to some degree, by oxidation and solution. From a field-study, it was found that other portions of the same rock-mass had been reduced to a coarse sand, in which decomposition had advanced no further than in the above case. The minerals composing the residual sand were quite fresh looking grains of quartz, feldspar and biotite.

A weighed portion of the finely powdered fresh rock, digested for three hours in 100 c.c. of boiling half-normal hydrochloric acid, yielded 10.98 per cent. of soluble matter. A portion of the partially decayed rock, treated in the same way, gave 12.69 per cent. of soluble matter.

FOLIATED PORPHYRITIC GRANITE (GRANITE-GNEISS), NEAR CAMAK, WARREN COUNTY

The rock shows a pronounced foliated structure, secondarily induced. The larger quartz and feldspar grains are drawn out and enclosed between the biotite layers forming distinct "augen," at times. The rock carries an abundance of black biotite, arranged along roughly parallel lines. Large white-opaque and pink porphyritically developed feldspars (phenocrysts), bearing numerous enclosed plates of biotite and other microscopic inclusions of the ground-mass minerals, occur. The further effects of dynamo-metamorphism are manifested in the frequently mashed and drawn-out quartz and feldspar crystals, in directions parallel with the biotite layers. The feldspar phenocrysts are always badly fractured.

The pronounced schistose structure is apparent, in thin sections under the microscope. The rock is composed of an aggregate of interlocking quartz and feldspar crystals, in which lie stout biotite shreds. The porphyritic potash feldspars are usually large and irregularly bounded phenocrysts, embedded in a coarse-grained ground-mass of quartz, feldspar and biotite. Orthoclase, microcline and some laths of plagioclase near oligoclase constitute the feldspathic constituent. Twinning is very common among the feldspars. The usual microscopic accessories, apatite, zircon and a little magnetite are present. The biotite is partially altered to a dark, opaque chlorite, and occasional crystals of slightly pleochroic and strongly double-refracting epidote.

The specimen of decayed rock, represented by a chemical analysis in column 2, table VII, was collected near the bottom of a 10-foot cut along the public wagon-road, between a small stream and Mr. Brinkley's dwelling house. The decomposed material in the cut is a yellowish-red and white, highly plastic clay. A few quartz stringers were found cutting the clay-mass in places. When rubbed between the fingers, the clay is distinctly gritty, owing to the presence of free quartz and undecomposed silicates. The biotite folia in the clayey product are in a nearly leached condition. They are slightly brass-yellow in color, and have lost all the physical properties, characteristic of the fresh mineral. The feldspar phenocrysts are reduced to a white, opaque, chalky mass, preserving in every detail the original outline of the fresh mineral. These are distributed through the red clay, derived from the decay of the ground-mass minerals.

When treated with dilute hydrochloric acid, to remove the iron stain, a white residue of quartz, some mica, and an abundance of kaolinized feldspars remained. Under the microscope, the residue was composed largely of a white, opaque material, taken to be kaolin, with a good proportion of the undecomposed silicates, readily recognizable. On breaking the large phenocrysts, that had apparently become kaolinized, the microscope indicated a center or core of nearly fresh feldspar.

Fig. 1

Fig. 2

THE LYELL GULLIES, CUT BY EROSION INTO THE RESIDUAL CLAY, RESULTING FROM THE WEATHERING OF GRANITE ROCKS, FOUR AND A HALF MILES WEST OF MILLEDGEVILLE, GEORGIA. IN THE EARLY PART OF THE NINTEENTH CENTURY, THEY WERE VISITED AND SUBSEQUENTLY DESCRIBED BY SIR CHARLES LYELL, IN HIS GEOLOGICAL WRITINGS.

TABLE VII

Analyses of Fresh and Decomposed Porphyritic Biotite Granite, from the Brinkley Place near Camak, Warren County, Georgia

Constituents	Fresh Rock	Decayed Rock	Recalculated on a Basis of 100		Percentage Loss for Entire Rock	Percentage of Each Constituent Saved	Percentage of Each Constituent Lost
	1	2	3	4	5	6	7
SiO_2	66.31	56.40	66.57	56.20	26.14	60.73	39.27
Al_2O_3 [1]	18.27	25.62	18.34	25.52	0.00	100.00	0.00
Fe_2O_3 [2]	2.51	3.45	2.52	3.44	0.04	98.28	1.72
CaO	2.91	0.37	2.92	0.37	2.65	9.13	90.87
MgO	1.22	0.98	1.23	0.99	0.51	58.23	41.77
Na_2O	3.69	1.36	3.70	1.35	2.73	26.26	73.74
K_2O	4.09	2.99	4.11	2.98	1.97	52.18	47.82
Ignition	0.61	9.18	0.61	9.15	0.00[3]	100.00	0.00[3]
Total	99.61	100.35	100.00	100.00	34.04		

[1] The alumina is assumed to be constant. [2] Ell iron was estimated as Fe_2O_3. [3] Gain.

Recalculated as before, the analyses show the results in columns 5, 6 and 7, of table VII. From the figures in column 5, a total loss for the entire rock of 34.04 per cent. has resulted. The increased percentage of water, as indicated by the ignition, is a natural consequence of hydration. Columns 6 and 7 show, that, of the essential constituents, the lime and soda salts have suffered most, although the potash, magnesia and silica have disappeared in somewhat large amounts. Calculated, on the assumption of an Al_2O_3 constant basis, column 6 indicates, that, of the original constituents, 60.73 per cent. of the SiO_2; 98.28 per cent. of the Fe_2O_3; 9.13 per cent. of the CaO; 58.23 per cent. of the MgO; 26.26 per cent. of the Na_2O; and 52.18 per cent. of the K_2O remain, in the change from fresh to decayed rock. The iron oxide has contributed but slightly to the material carried away in solution, differing but little from the assumptively insoluble alumina.

In this case, as in many of the even-grained granites discussed above, the weathering is far advanced, and the process is mainly in the nature of decomposition. It differs from the weathering of the massive porphyritic granite in Columbia county, in that the process represents an advanced, rather than an early, stage in the decay, with the conditions more in the nature of chemical decomposition than mechanical disintegration.

A weighed portion of the powdered fresh rock, treated for three hours with 100 c.c. of boiling half-normal hydrochloric acid, yielded 16.29 per cent. of soluble matter. A similar portion of the decomposed rock, treated in the same way, gave 23.67 per cent. of soluble matter.

PORPHYRITIC GRANITE, McCOLLUM QUARRY, NEAR COWETA STATION, COWETA COUNTY

When fresh, the rock is a very coarse-grained porphyritic biotite granite, medium-gray in color. Microscopically, it is composed of quartz, the potash feldspars (orthoclase and microcline) and an acid plagioclase (near oligoclase), with biotite. The orthoclase shows good cleavages, and is intergrown with a second feldspar (albite) in the form of microperthitic structure. Rounded disks or ovals of intergrown feldspar and quartz, as micropegmatitic structure, are quite common in thin sections of the rock. Large prismatic inclusions of apatite are more abundant than usual in the feldspars. Some epidote, chlorite and muscovite, as secondary products from the alteration of the feldspars and biotite, occur.

Both orthoclase and microcline are porphyritically developed. As a rule, the phenocrysts are characterized by numerous inclusions of the ground-mass minerals. Biotite occurs as a constant inclusion, and is usually in plates equally as large as those in the ground-mass. A thin section of one of the phenocrysts showed the characteristic microcline structure under the microscope. The phenocrysts often measure two inches and more in length; and, as a rule, are irregular in outline and grade into the ground-mass feldspars. Some of them are idiomorphic in crystal outline and tabular parallel to the clinopinacoid (010), and are commonly twinned according to the Carlsbad law. The (001) and (010) cleavages are usually well developed.

Chemical analyses of the carefully selected fresh and decomposed feldspar phenocrysts, from the McCollum porphyritic granite, yielded the writer the following results: —

	Fresh Feldspar	Decomposed Feldspar
Silica, SiO_2	64.40	59.70
Alumina, Al_2O_3	18.97	21.73
Iron Sesqui-oxide, Fe_2O_3	0.37	0.60
Lime, CaO	0.59	0.04
Magnesia, MgO	trace	trace
Soda, Na_2O	3.60	2.09
Potash, K_2O	11.40	13.80
Ignition	0.19	3.00
Total	99.52	100.96

Sp. G.—— 2.55 (Thoulet solution).

Assuming the percentage of water above 110° C., 2.32 per cent. in the above analysis of the decomposed feldspar, combined with sufficient amounts of the SiO_2 and Al_2O_3 to form kaolin, the computed amounts of the oxides, based on the formula $H_4Al_2Si_2O_9$,[1] are:—

SiO_2	7.68 per cent.
Al_2O_3	6.54 " "
H_2O	2.32 " "

After deducting the above percentages of SiO_2 and Al_2O_3 from the total percentages in the analysis, and disregarding the small fractional percentages of iron oxide and magnesia, we find by calculation, that the partially decomposed feldspar consists of 83.10 per cent. of the fresh orthoclase or microcline molecule, and 16.54 per cent. of the alteration product, kaolin.

The chemical changes, incidental to the alteration of this feldspar, are shown in the above analyses of the fresh and decayed mineral. The most striking features are: the assumption of nearly three per cent. of water, accompanied by a slight loss in the SiO_2 and Na_2O, while the Al_2O_3 and K_2O remain constant. Averaging the K_2O and Na_2O together as total alkalies, for the fresh and decomposed feldspar respectively, a slight loss is noted on the assumption of an Al_2O_3 constant basis.

No trace of carbonates could be detected in the decomposed mineral, when treated with dilute acid. When not stained with iron oxide, derived from the decomposition of the biotite, the partially decomposed feldspar crystals are white and chalky in appearance. They readily crumble into a gritty feldspathic sand, under moderate pressure of the fingers. Under the microscope, the sand appears glassy and opaque, from partial kaolinization, usually showing high double-refraction colors of the fresh feldspar particles. From an outward appearance, the phenocrysts seem to be completely decomposed; but chemical and microscopic study indicate, that they are more than two-thirds fresh. The decay has evidently progressed exteriorly along the cleavage planes, by the assumption and consequent action of water.

Although the feldspar phenocrysts indicate an advanced stage of decay, the large included plates of biotite are always found in an almost perfectly fresh condition, with no visible signs of alteration apparent to the naked eye.

Several hundred yards north of Coweta station, in the railroad-cut, is an excellent section of the decayed porphyritic granite, extending to a depth of from 20 to 30 feet. The color of the

[1]Dana, E. S., A Text-Book of Mineralogy, New Edition, 1898, p. 481.

residual product at this point is prevailingly light-gray, stained a dull yellow from the partial decomposition of the biotite, and mottled with the large white kaolinized feldspar phenocrysts. Masses of the fairly fresh, hard and firm rock, are distributed through the clay residual in places. The feldspars indicate an advanced stage of kaolinization, although when broken an abundance of the fresh mineral is apparent. The biotite is partially leached and stained from the oxidation of its iron. The rock outcrops are readily traceable for 5 miles north of Coweta station, along the railroad and the public wagon-road. Numerous contacts between the residual products of the porphyritic granite and the mica-schist were observed along both the wagon-road and railroad between Coweta station and Palmetto—a distance of 5 miles. On the east side of the railroad, 3½ miles south of Palmetto, are gullies, from 15 to 20 feet deep, trenched in the red and gray residual granite clay.

The rock at Coweta station is a thin, foliated mica-schist, which is in immediate contact with the porphyritic granite, several hundred yards to the north in the railroad-cut. The contact is between deeply decayed schist and porphyritic granite; and, owing to the difference in the residual products of the two rocks, the demarkation is sharp and distinct. The mica-schist forms a deep-red residual clay; while the granite residual is usually light-gray in color, and contains a large proportion of the nearly fresh minerals.

In table VIII, are given analyses of the fresh and partially decayed rock. Column 3 shows an analysis of the partially decayed porphyritic granite collected from several places in the railroad-cut, approximately 300 yards north of Coweta station. The material consists of a light-gray mass of partially fresh and decomposed minerals. The feldspars are considerably kaolinized, and the biotite, partially leached and oxidized; although, as a rule, the latter mineral is almost entirely fresh. Free quartz is very abundant in the decayed product. Of the minerals present, the feldspar has suffered the most from weathering.

TABLE VIII

Analyses of Fresh and Partially Decomposed Porphyritic Biotite Granite, from the McCollum Quarry, near Coweta Station, Coweta County, Georgia

Constituents	Fresh Rock	Partially Decayed Rock	Partially Decayed Rock	Recalculated on a Basis of 100			Percentage Loss for Entire Rock	Percentage of Each Constituent Saved	Percentage of Each Constituent Lost
	1	2	3	4	5	6	7	8	9
SiO_2	63.65	60.28	53.58	63.12	60.28	53.97	24.84	60.64	39.36
Al_2O_3	20.46	22.45	26.27	20.29	22.45	26.46	1.51	92.51	7.49
Fe_2O_3 [1]	2.20	2.53	3.07	2.18	2.53	3.09	0.00	100.00	0.00
CaO	3.28	0.83	0.17	3.25	0.83	0.17	3.12	3.71	96.29
MgO	1.50	0.58	1.44	1.49	0.58	1.45	0.46	69.04	30.96
Na_2O	4.75	7.84[2]	1.88	4.71	7.84[2]	1.89	3.36	28.46	71.54
K_2O	4.58		3.85	4.54		3.88	1.78	60.62	39.38
Ignition	0.42	5.49	9.02	0.42	5.49	9.09	0.00[3]	100.00	0.00[3]
Total	100.84	100.00	99.28	100.00	100.00	100.00	35.07		

[1] The iron oxide is assumed to be constant. All iron was estimated as Fe_2O_3. [2] Calculated by difference. [3] Gain.

Recalculated as before, the analyses give the results shown in columns 7, 8 and 9, of table VIII. From the figures given in the table, it appears that the lime and soda salts have been removed in the largest quantities, with the potash, silica and magnesia, next. All the ferric oxide has been retained, and only a slight loss in the alumina is shown. The change has been accompanied by a gain in water, as shown by the ignition, and a total loss of all the constituents, amounting to 35.07 per cent. of the entire rock.

Of the original constituents, 60.64 per cent. of the SiO_2; 92.51 per cent. of the Al_2O_3; all the Fe_2O_3; 3.71 per cent. of the CaO; 69.04 per cent. of the MgO; 28.46 per cent. of the Na_2O; and 60.62 per cent. of the K_2O, remain.

The figures indicate a considerable removal of the more soluble constituents in solution, derived mostly from the feldspars. The change, while far from being complete, as shown by the relatively large proportion of the fresh minerals present, has principally been one of decomposition. In the earlier stages of the process, the chemical agencies were apparently very active; as manifested in the readiness, with which the feldspars were converted into partially kaolinized areas. The mica also shows very appreciable alteration in this stage, although yielding much less readily than the feldspars.

A weighed portion of the finely powdered fresh rock, from a portion of the same porphyritic granite mass, near Line creek in Fayette county, digested for three hours in 100 c.c. of boiling half-normal hydrochloric acid, gave 9.47 per cent. of soluble matter.

III. Granite-gneiss

The Lithonia area of contorted granite-gneiss in DeKalb county, best illustrates the character of, and the changes incidental to, the weathering, common to this type of rock in Georgia. It has been shown elsewhere in this report, that those gneisses of Piedmont Georgia, studied by the writer, are closely similar to the granites, in chemical and mineralogical composition, and are accordingly metamorphosed granites. The gneisses are distinguished from the massive granites only by a pronounced banded or schistose structure, subsequently induced by metamorphism. As before stated, they are, on account of their origin, referred to as granite-gneisses, in contradistinction to gneisses of known sedimentary origin.

The sap (partially decayed surface-rock) of the doming-masses of the Lithonia granite-gneiss, and the adjacent famous Stone Mountain granite boss, is very thin, rarely averaging, as a rule, more than two inches in thickness. It is hard and firm surface-rock, discolored to a slight red from the partial hydration and oxidation of the biotite. The feldspars are dull and opaque from kaolinization ; and, in most cases, the rock indicates alteration to a greater depth than the discolored portion. This is manifested, by a general dullness in appearance of the stone through more or less feldspathic alteration.

Like the Stone Mountain boss of granite, the large doming-masses of the granite-gneiss rise to elevations, from 15 to 100 feet above the adjacent lowland plain in the vicinity of Lithonia. That part of the plain, immediately adjacent to the doming-masses of gneiss, is coextensive with and forms a part of the Georgia Piedmont plain. In this locality, it marks the reduced portions of the granite bosses—unreduced residuals. In this plain, and skirting the bosses of granite-gneiss, are numerous exposed sections of apparently completely disintegrated and decomposed granite-gneiss, varying in depth from 10 to 15 feet. The schistosity of the original fresh rock is almost perfectly preserved in the residual clays composing these sections.

Microscopically, the gneisses are composed of quartz, orthoclase and microcline—the two latter intergrown with a second feldspar (albite) as microperthitic structure—an acid plagioclase near oligoclase, and biotite. A little magnetite, some apatite, and zircon are present. More or less chlorite, muscovite and epidote occur as secondary minerals, derived from the alteration of the feldspars and biotite. The potash feldspars predominate, and the species vary in amount, from place to place. Microcline is somewhat more abundant than in the true granites and porphyritic granites. The plagioclase also varies in amount. The analyses, in the percentage of lime present, corroborate the inference, that the plagioclase is oligoclase. The analyses also indicate a larger percentage of free quartz, than is contained in the granites and their porphyritic facies. This is confirmed by the microscope. The larger feldspar crystals contain drop-like inclusions of quartz and feldspars. Peripheral shattering of the larger quartz and feldspar crystals, numerous lines of fracture, and wavy extinction, common to these two minerals, afford evidence of the effects of dynamo-metamorphism.

The partially decomposed gneiss, a chemical analysis of which is given in column 2, table IX, was a finely divided white product, containing abundant mica folia and undecomposed feldspar and quartz, distributed through the mass. The material was collected several feet below the surface near the Crossley quarry, which occupies a portion of the western erosion slope of Pine Mountain—a large boss of contorted granite-gneiss.

TABLE IX

Analyses of Fresh and Partially Decomposed Biotite Granite-Gneiss, from the Crossley Quarry, near Lithonia, DeKalb County, Georgia

Constituents	Fresh Rock	Partially Decomposed Rock	Partially Decomposed Rock	Recalculated on a Basis of 100			Percentage Loss for Entire Rock	Percentage of Each Constituent Saved	Percentage of Each Constituent Lost
	1	2	3	4	5	6	7	8	9
SiO_2	76.00	73.48	71.67	75.82	72.95	71.12	21.74	71.33	28.67
Al_2O_3	13.11	14.78	16.14	13.08	14.67	16.02	0.90	93.13	6.87
Fe_2O_3 [1]	0.92	1.30	1.22	0.92	1.29	1.21	0.00	100.00	0.00
CaO	1.06	0.31	0.29	1.05	0.31	0.29	0.83	21.01	78.99
MgO	0.27	trace	0.10	0.27	trace	0.10	0.20	28.57	71.43
Na_2O	3.88	3.43	2.80	3.87	3.41	2.78	1.75	54.72	45.28
K_2O	4.69	5.00	4.52	4.68	4.97	4.48	1.27	72.84	27.16
Ignition	0.31	2.42	4.03	0.31	2.40	4.00	0.00[2]	100.00	0.00[2]
Total	100.24	100.72	100.77	100.00	100.00	100.00	26.69		

[1] The iron oxide is assumed to be constant. All iron was estimated as Fe_2O_3. [2] Gain.

Recalculating the analyses of the fresh and decomposed granite-gneiss to a basis of 100, and assuming the iron oxide to remain constant, the calculated amounts of each constituent, saved and lost, appear in columns 7, 8 and 9, of table IX. Of the original constituents, 71.33 per cent. of the SiO_2; 93.13 per cent. of the Al_2O_3; all the Fe_2O_3; 21.01 per cent. of the CaO; 28.57 per cent. of the MgO; 54.72 per cent. of the Na_2O; and 72.84 per cent. of the K_2O have been retained. This corresponds to a total loss of contituents for the entire rock, of 26.69 per cent. The magnesia is present in such small amounts in the rock, as to render the results somewhat unreliable. It appears, therefore, that the lime and soda salts have been removed in the largest proportions, with the silica and potash next; while the alumina has suffered but slight loss. Here, as in the cases described above, the change from fresh to decayed rock has been accompanied by a gain in water—*hydration.*

In some places over the belt, the decayed granite-gneiss is a highly ferruginous stained mass, in which the mica has suffered greater alteration than the feldspars. In such cases, the rock is still moderately firm material, just beginning to crumble. This is especially true of the Southern Granite Company's quarry, located on the eastern side of the belt. For this reason, analyses of the fresh and the partially weathered rock were made, of specimens collected from the above quarry; and the two were averaged with similar analyses of the Crossley quarry rock, the results being recorded in table X.

TABLE X

Analyses of Fresh and Partially Decomposed Contorted Biotite Granite-Gneiss, near Lithonia, DeKalb County, Georgia. Average of Analyses of Fresh and Decomposed Rock from the Southern Granite Company's Quarry and the Crossley Quarry

Constituents	Fresh Rock	Decomposed Rock	Recalculated on a Basis of 100		Percentage Loss for Entire Rock	Percentage of Each Constituent Saved	Percentage of Each Constituent Lost
	1	2	3	4	5	6	7
SiO_2	74.48	73.22	74.72	72.72	6.04	91.91	8.09
Al_2O_3 [1]	13.90	14.87	13.94	14.77	0.00	100.00	0.00
Fe_2O_3 [2]	1.10	1.22	1.10	1.21	0.00[3]	100.00	0.00[3]
CaO	1.17	0.51	1.18	0.51	0.70	40.80	59.20
MgO	0.17	0.04	0.17	0.04	0.13	22.22	77.78
Na_2O	4.03	3.52	4.04	3.49	0.74	81.54	18.46
K_2O	4.56	4.90	4.58	4.86	0.00[4]	100.00	0.00[4]
Ignition	0.27	2.42	0.27	2.40	0.00[5]	100.00	0.00[5]
Total	99.68	100.70	100.00	100.00	7.61		

[1] The alumina is assumed to be constant. [2] All iron was estimated as Fe_2O_3. [3] Very slight gain.

[4] No loss on the assumption of an Al_2O_3 constant. [5] Gain.

In this table, the percentage amounts of the constituents lost are less, with the single exception of the MgO, than those given in table IX. By assuming the Al_2O_3 to remain constant, only four of the constituents indicate a loss. These are SiO_2, CaO, MgO and Na_2O. Of these, the lime has disappeared in the largest quantity; while the Fe_2O_3, K_2O and H_2O (ignition) indicate slight gains. The change has been accompanied by a total loss for the entire rock of only 7.61 per cent.

The process has been largely one of hydration, accompanied by oxidation of the iron of the biotite, in a supply of oxygen, sufficient to retain the newly formed product, iron sesqui-oxide.

Weighed portions of the finely powdered fresh rock, collected from several places over the Lithonia area of contorted granite-gneiss, and digested in 100 c.c. of boiling half-normal hydrochloric acid, for three hours, gave the following percentage amounts of soluble matter:—

Southern Granite Company's Quarry	7.58 per cent.
Arabia Mountain, DeKalb County	6.06 " "
Tilley Quarry, Rockdale County	5.94 " "
Average	6.52 " "

Résumé

After a careful study of the preceding tables of analyses of the fresh and decayed Georgia granitic rocks, the amount of water is observed to increase very rapidly as the decomposition advances, which, as Merrill has shown,[1] becomes the most important factor in the earlier stages of rock degeneration. The change has, in every case, been accompanied by a loss in the silica, a greater proportional loss in the alkalies, the lime and the magnesia, with a proportional increase in the iron oxide, and, in some cases, in the alumina.

Free quartz, when present in igneous rocks, is known to be the most refractory of the component minerals toward purely chemical agents. The amount lost, therefore, from this source, under normal atmospheric conditions must necessarily be small.

The most striking illustration of differential weathering among the component minerals, yet seen in the granitic rocks of the State, is shown in an extensive area of a coarse-grained porphyritic granite in the southeast part of Bartow county, Georgia, directly on the east side of the Cartersville fault.[2] The granite is surrounded, on

[1] Rocks, Rock Weathering and Soils, 1897, p. 234.

[2] Hayes, C. W., Bull., Geol. Soc. Amer., 1891, Vol. II, pp. 141-154.
Ibid., Trans., Amer. Inst. Min. Engrs. Read at the Washington Meeting, February, 1900.
Also, Spencer, J. W., The Paleozoic Group, Geol. Surv. of Ga., 1893, pp. 28, 60 and 84.

all sides, by sedimentaries—quartzite, black graphitic slates and schists, of Algonkian age. Most of the granite has undergone considerable alteration from dynamo-metamorphism, and is accordingly converted into an augen-gneiss. The rock is composed of large porphyritic crystals of microcline from 15 to 50 mm. in length, in a ground-mass of blue quartz, plagioclase and mica. The metamorphism is so extreme in portions of the area, that the component minerals, quartz, feldspar and mica, are completely differentiated into parallel, alternating thin bands. The feldspar and quartz form alternating layers of nearly equal thickness, varying from 1-16 to 1-8 of an inch; while the mica layers scarcely vary from the thickness of a knife-edge. Where this phase of the rock is exposed in ledge-form along the dissected stream-courses, notably near the confluence of Stamp creek with the Etowah river, conditions have been especially favorable for emphasizing the differential chemical erodibility (etching and solution) of the different mineral layers. The feldspar and mica layers are etched, or dissolved, out to a depth of from 1-32 to 1-4 inch, and, in extreme cases, 1-2 inch, below the surface of the quartz bands, thus proving, in this case, the very slight comparative effect of chemical agencies in the destructibility of quartz. The edges of the quartz layers, however, are more-or-less rounded, from some chemical action.

The following is an analysis, by Dr. H. N. Stokes, in the chemical laboratory of the U. S. Geological Survey, of specimens of this granite collected by Mr. A. H. Brooks :—

Silica, SiO_2	67.98
Alumina, Al_2O_3	14.84
Iron Sesqui-oxide, Fe_2O_3	1.00
" Protoxide, FeO	3.15
Magnesia, MgO	0.91
Lime, CaO	2.17
Soda, Na_2O	2.66
Potash, K_2O	4.76
Water, H_2O, at 110° C.	.14
" H_2O, above 110° C.	.49
Titanic Oxide, TiO_2	.84
Phosphorus Pentoxide, P_2O_5	.34
Manganous Oxide, MnO	trace
Baryta, BaO	.20
Strontia, SrO	trace
Lithia, Li_2O	trace
Sulphur, S	.08
" Tri-oxide, SO_3	trace
Chlorine, Cl	trace
Fluorine, F	trace
Carbon, C (Graphite)	.21
Total	99.77

The following is Brooks's description of the rock: "Augite-microcline-granite, 1 mile east of Rowland, Bartow county, Ga. Contains microcline, some plagioclase, abundant pyroxene partly altered into chiefly uralite and chlorite, some biotite with frequent inclusions of rutile, much blue vitreous quartz, apatite, zircon, and magnetite."[1]

Still another noteworthy illustration of differential weathering among the component minerals of very coarse-textured rocks, in which the resistance offered by quartz to the usual atmospheric chemical agents is emphasized, is found in the numerous pegmatitic veins, which characterize the larger granite exposures. The veins vary in width, and are composed, principally, of coarse crystallizations of feldspar and quartz, with a little biotite and, occasionally, some muscovite. In all the sections examined, of the decayed granite enclosing these veins, the feldspar of the veins is either partially or entirely decomposed into the secondary clayey product; while the intimately associated quartz crystals preserve the angular edges and fresh condition of the original mineral, with only slight, if any, chemical effect shown.

This point is further illustrated, in the numerous quartz veins, so common throughout the crystalline area of the Southern Appalachians. The ferro-magnesian silicate rocks enclosing the veins are frequently weathered to a clayey mass, for a depth of from 30 to 75 feet and more; while the veins of quartz retain their original outline and structure, as preserved in the perfectly fresh rocks. The quartz is broken and fractured; but the edges are more or less angular, indicative of only slight solvent action, or etching.

The decayed product of the Georgia granites invariably shows an abundance of quartz grains, derived from the free quartz in the original fresh rock. In most cases, the quartz granules have been only slightly corroded, and are usually more or less angular in outline. Frequent examinations of the quartz grains in the residual clays were made under the microscope, for evidence of etching and solution; but positive evidence was lacking, in every case. The loss, therefore, of this constituent in these rocks has been derived in large part, if not entirely, from the silicates, feldspar and biotite. It was doubtless removed with the alkaline solutions of the more soluble constituents, during the process of decomposition, hydration and solution, as it was liberated in the free (nascent) state.

[1]Bull., No. 168, U. S. Geol. Surv., p. 55.

It has been shown, however, by Ebelmen[1] and others,[2] that rocks, composed of silicates, almost or entirely lacking in alkalies, lose a portion of their silica with equal readiness. This has been explained on the supposition, that, as the silica was liberated in the nascent state, it was soluble either in pure or carbonated water.

The iron is mostly present in these rocks as ferrous iron. The stability of this constituent, characterizing all the preceding analyses of the fresh and decayed rocks, may be readily accounted for, on the supposition, that the decomposition was promoted in a sufficient supply of oxygen, whereby all the iron was converted into the form of insoluble hydrated sesqui-oxide, and retained with the residue. As seen from the accompanying tables, the alumina has suffered only a slight loss in most cases ; while all this constituent has been retained in a few others.

The lime, magnesia and alkalies obey the usual laws in the proportional amounts, lost and saved, for such rocks. The lime has invariably disappeared in larger percentage amounts, than the magnesia; and likewise, the sodium salts have been removed, as a rule, in larger quantities than those of potassium. The feldspars are, of course, the principal source of the soda and potash in the rocks; and the removal of soda, in larger amounts than the potash, indicates, that the potash feldspars are more refractory toward normal atmospheric agencies, than the soda-lime, or plagioclases.[3]

The accessories, tourmaline, magnetite, zircon and garnet, all occur to some extent in the residual granite sands, scarcely affected at all by the atmospheric agents.

In the most advanced stages of decay, the product is a highly plastic ferruginous clay, rendered gritty by the presence of free quartz granules mainly, together with a small percentage of the undecomposed silicates. In such cases, the transition from fresh to decomposed rock has been accompanied by an unusually large proportional loss in the constituents, greatly exceeding, in several instances, 50 per cent.[4] Here, the change is not far from completion; as is shown, not only in the chemical analyses, but in the relatively small amounts of undecomposed minerals present in the clay as well. In these cases, where the change is accompanied by so large a total loss in the constituents for the entire rock, the process is an advanced one, and entirely in the nature of chemical

[1] *Ann. des Mines*, 1845. Vol. VII.

[2] See Merrill, Geo. P., Rocks, Rock-Weathering and Soils, 1897, pp. 226 and 227.

[3] *Roth's Allegemeine u. Chemische Geologie*, 3rd Edition, 2nd Heft.
Geldmacher, M., *Beitrage zur Verwitterung der Porphyre*, Leipzig, 1889.
Lemberg. Zeit. der Deut. Geol. Gesellschaft, 1876, 28.

[4] Merrill, Geo. P., Rocks, Rock-Weathering and Soils, 1897, p. 234.

decomposition. In the earlier stages of weathering, the rock begins to crumble, and is ultimately reduced to a light-gray granitic sand, by hydration and temperature changes, the disintegration being accompanied by only slight chemical change. The following summary of results, showing the total percentage loss of the constituents for the entire rock, in the various stages of decay, as calculated from the analyses in the preceding tables, will indicate to some extent, whether the process involved has been mainly one of decomposition or disintegration :—

	Total Percentage Loss for Entire Rock
The Swift and Wilcox Quarry, near Elberton	7.92
The Coggins Quarry, near Oglesby, partially decomposed rock	7.71
The Lexington Blue Granite Quarry, near Lexington	14.56
The Heggie-Rock, Columbia County	15.84
The Crossley Quarry, near Lithonia	26.69
The Brinkley Place, near Camak	34.04
The McCollum Quarry, Coweta County	35.07
The Cole Quarry, near Newnan	38.45
The Coggins Quarry, near Oglesby	44.72
The Greenville Granite Company's Quarry, near Greenville	61.98
" " " " " " "	71.84

Observations in various latitudes and climates, on the breaking down of granitic rock-masses, in which potash feldspar and biotite occur as essential minerals, indicate, that biotite, as a rule, is the first to yield to atmospheric decomposition; and, in many cases, it almost entirely disappears. There are many exceptions, however, to this.

In the Georgia rocks, it is observed, that for some localities the mica begins to give way first; while, in others, the feldspar appears to be the most easily affected; and, in others still, the rate of decomposition is seemingly about equal for the two. The problem is somewhat complicated, however, in the case of the Georgia granitic rocks, on account of the large proportion of soda-lime feldspar (plagioclase) present, and the abundance of microperthitic intergrowths, common to the potash species.

During the early stages of weathering in these rocks, chemical decomposition was subordinated to physical disintegration; and the rocks suffered mainly through temperature changes, such as produce granulation and weakening in the cohesive power between the individual minerals, feldspar and biotite, resulting in crumbling along the planes of cleavage.

Freezing and solution have aided in the process; but, owing to the low absorptive power of the Georgia rocks, they cannot be considered as the first important factors. The following tabular statement shows the percentage, or ratio, of absorption for the Georgia granites, determined by the writer in the laboratory of the Geological Survey :—

	Percentage of Absorption
The Charley Rocker Quarry, Hancock County	0.037
The Sparta Quarry, Hancock County	0.049
The Lexington Blue Granite Quarry, Oglethorpe County	0.092
The Diamond Blue Granite Co.'s Quarry, Oglethorpe County	0.088
The Swift and Wilcox Quarry, Elbert County	0.090
The Swift and Wilcox Flat Rock, Elbert County	0.092
The Tate and Oliver Quarry, Elbert County	0.093
The Coggins Granite Quarry, near Oglesby, Elbert County	0.090
The L. D. Childs Quarry, near Oglesby, Elbert County	0.092
The Snell Quarry, Gwinnett County	0.075
The W. W. Linch Quarry, near Eatonton, Putnam County	0.060
The Greenville Granite Co.'s Quarry, Meriwether County	0.086
The Odessa Quarry, Meriwether County	0.056
The Stone Mountain Granite Quarries, DeKalb County	0.067
The Arabia Mountain Granite Quarries, DeKalb County	0.050
The Pine Mountain (Little Stone Mountain) Granite Quarries, DeKalb County	0.052

The process of disintegration, must in the beginning, necessarily be a very slow one. Constant expansion and contraction of the component minerals, aided by alternate freezing and thawing, and, to some degree, by kaolinization of the feldspars and rusting of the biotite, causing the cleavable minerals to split along the lines of cleavage, have been the essential factors in producing the change in the early crumbling of the Georgia granitic rocks.

From this stage on, in the weathering, the processes involved, in the change from fresh rock to residual clay, are more in the nature of decomposition (chemical) than disintegration (physical).

The fact, that granitoid rocks may undergo extensive disintegration, with but slight decomposition, has been emphasized by several writers. Nordenskiöld observed the sharp contact between the weathered and unweathered granitic rocks in Ceylon, and remarked, that the rock crumbles to a sand, without the formation of clay, and accompanied by only slight chemical change.[1]

The same features have been detailed by Merrill, in his studies of the weathering of the granitic rocks of the District of Columbia.[2] A similar tendency toward disintegration, without decomposition, is well illustrated in the coarsely crystalline rocks of the Pike's Peak (Colorado) area, where Crosby, quoted by Merrill,[3] gives it as his opinion, that the granites of this area disintegrate

[1] Voyage of the Vega, 1881, Vol. II, p. 420, quoted by Merrill, Rocks, Rock-Weathering and Soils, 1897, p. 242.

[2] Bull., Geol. Soc. Amer., 1895, Vol. VI, pp. 321–332; also, Rocks, Rock-Weathering and Soils, 1897, pp. 206–213.

[3] *Ibid.*, p. 243.

mainly through hydration, the mica, particularly, being affected. Among finer-grained rocks, such as the Fourche Mountain (Arkansas) syenites, decomposition is said to follow so closely on disintegration, that practically no sand is formed.

Numerous cases, where the rocks have been resolved into residual products, from disintegration with but little decomposition, and also, where decomposition follows so closely on disintegration, and greatly predominates, are well illustrated among the various types of Georgia granitoid rocks described above. The data are yet insufficient, however, to draw any definite conclusions, concerning the character of the weathering of the fine- and coarse-grained granites of the State. That is, to say definitely, whether the coarse-grained varieties suffer mainly from disintegration, and the fine-grained ones, by disintegration closely followed by decomposition.

The early stages in the processes of weathering, as elsewhere pointed out in this paper for each type (fine- and coarse-grained) of the Georgia rocks, is mainly one of disintegration accompanied by some chemical change; while the later stages are as prevailingly characterized by decomposition, resulting in the production of a stiff, plastic red clay. The earlier stages, in the weathering of the fine-grained granites, are apparently the same, as for the similar stages in the coarse-grained porphyritic granites. The same statement holds, for the two types in the advanced stages of weathering—decomposition.

The striking similarity, in the granite, porphyritic granite and granite-gneiss, is well illustrated in the percentage amounts of soluble matter, extracted from weighed portions of finely powdered fresh rock, by digestion in 100 c.c. half-normal hydrochloric acid, for three hours, at the temperature of boiling water, as follows:—

GRANITES	Per Cent. of Soluble Matter
The Oglesby Blue Granite, Elbert County	10.56
The Diamond Blue Granite Quarry, Oglethorpe County	9.77
Light-gray Granite, Swift & Wilcox Quarry, Elbert County	9.20
Light-gray Granite, Echols Mill, Oglethorpe County	8.37
Average	9.475
PORPHYRITIC GRANITE	
The Heggie-rock, Columbia County, coarse-grained Porphyritic Granite	10.98
The Heggie-rock, Columbia County, coarse-grained Porphyritic Granite (decayed)	12.69
Coarse-grained Foliated Porphyritic Granite, near Camak	16.29
Coarse-grained Foliated Porphyritic Granite, near Camak (decayed)	23.67
Coarse-grained Porphyritic Granite, near Line Creek	9.47
Average of Fresh Rock	12.246

GRANITE-GNEISS

Contorted Biotite Granite-Gneiss, Southern Granite Co.'s Quarry, Lithonia	7.58
Contorted Biotite Granite-Gneiss, Arabia Mountain Quarries	6.06
Contorted Biotite Granite-Gneiss, Tilly Quarry, Rockdale County	5.94
Average	6.526

The lower percentage amount of soluble matter in the granite-gneisses over the granites and their porphyritic facies is readily accounted for on the basis of this rock-type containing a larger amount of free quartz, as seen from the tables of chemical analyses. The inference is also corroborated by microscopic study.

In each case, where the total percentage of extract from the decayed product was estimated, an increase over the corresponding extract from the fresh rock was indicated. Merrill has shown, that the total amount of soluble matter, extracted from the fresh rock, exceeded, in some cases, that from the corresponding decayed product in some of the basic rocks.[1] This is accounted for by Merrill, on the basis, that disintegration accompanied by decomposition and leaching-action in the weathered rock has resulted in the removal of a portion of the more soluble constituents.

The Cause of the Red Color of the Soil

The cause of color variation in soils has been discussed in recent years, principally by Crosby,[2] Dana,[3] Russell[4] and Merrill.[5] After extended and careful detailed work in the crystalline rocks of the Southern Appalachians, the writer's observations are, thus far, in accord with those of Crosby and Merrill, in supposing this to be a superficial phenomenon. The most brilliant hues in the above region are observed to be confined to the immediate surface portions of the decayed rock, varying from an inch to many feet in depth. These gradually give way, in turn, to more modest hues of yellow and brown, and finally pass into grays and other colors of the fresh parent rock beneath, as the depth increases. Such a transition may be observed in almost any recent excavation in the crystalline belt of the Southern Appalachians. There are, however, two exceptions to this, which, without proper differentiation, will prove very misleading: First, in those cases, where the sections have been ex-

[1] Rocks, Rock-Weathering and Soils, 1897, p. 219. Bull., Geol. Soc. Amer., 1896, Vol. VII, pp. 349-362.

[2] Proceedings, Boston Soc. Nat. Hist., 1884-1888 (1888), Vol. XXIII, pp. 219-222. Technological Quarterly, 1891, Vol. IV, p. 36.

[3] Amer. Jour. Sci., 1890, Vol. XXXIX, pp. 317-319.

[4] Bull. No. 52, U. S. Geol. Surv., 1889, 65 pp.

[5] Bull., Geol. Soc. Amer., 1897, Vol. VIII, pp. 161-162. Rocks, Rock-Weathering and Soils, 1897, pp. 384-386.

THE NORTH AVENUE PRESBYTERIAN CHURCH, ATLANTA, GEORGIA, BUILT OF STONE MOUNTAIN GRANITE.

posed for some time, the transition in vertical section becomes quickly obscured by the washing down from above, of the brilliant ochreous coloring matter, frequently coating the section-face to the entire depth of exposure, with a varying thickness of the ferruginous wash. This invariably happens, and may be observed to advantage, after heavy rains in almost any part of the above belt. Second, in other cases, exceptions are found in the weathering along joint-planes and other approximately vertical as well as horizontal planes of weakness, found cutting the rock-masses. In these, the color is most intense along the immediate surface of the planes and extends, in case of the vertical planes, to a considerable depth, in most cases.

Crosby is inclined to regard the increase in color of the superficial portions, to be due wholly to dehydration of the ferric salts; while Merrill recognizes, not merely the *quality* of the coloring matter, but also the *quantity*, emphasizing the latter. He says:[1] "This is well shown in the fractional separations, made by washing these residual clays and sands, whereby they are separated into proportional parts of varying degrees of fineness." This point has been particularly emphasized by the writer in the description and treatment of the residual products of the granites described above.

Recent writers have shown, that rock-weathering, in warm and moist climates, is accompanied by a leaching process, in which the more soluble constituents are more or less gradually removed in solution. Furthermore, that, of the essential constituents occurring in rocks, the ferric and alumina salts, are found to be the most refractory. The resulting final product of decomposition consists, therefore, of a highly ferruginous clay, composed mainly of the hydrated aluminous silicates, free iron sesqui-oxides, and, in the case of acid rocks, additional free silica.

Merrill remarks, that, all things being equal, the depth or degree of color indicates advanced decomposition, and also geological age.[2] This statement accords well with the writer's work and observations on the Georgia granites. The gray soils, derived from the granitoid rocks of the State, represent, not an advanced stage of decomposition, but mainly a process of disintegration, aided, to a limited extent only, by decomposition, manifested in the partial kaolinization of the feldspars, and a slight rusting (oxidation) of the biotite; while the red soils, derived from the same rocks, are invariably deep-red, ferruginous clays, in which the biotite is thoroughly leached and oxidized, and the feldspars nearly, if not en-

[1] Bull., Geol. Soc. Amer., 1897, Vol. VIII, p. 162.

[2] *Ibid.*, p, 162. Also, Rocks, Rock-Weathering and Soils, 1897, p. 386.

tirely, kaolinized. Stated somewhat differently, the gray soils contain an abundance of all the component minerals present in the fresh rock; but they are only slightly altered chemically; are highly porous, sandy soils, from which clay is essentially absent; and have been derived from the fresh rock, chiefly by disintegration. The red soils, on the other hand, contain comparatively a very small percentage of the undecomposed silicates; are deep-red, ferruginous, stiff clays, rendered more or less gritty by the presence of free quartz and the undecomposed silicates; and have resulted from decomposition. The gray soils represent, therefore, the earlier stages (disintegration) in the weathering of the rocks; while the red soils are, conversely, the products of decomposition, and represent the advanced stages in the change.

While *quantity* of pigment (ferric oxide) seemingly controls, within certain limits, or rather accounts for, the brilliant coloring of the soils in general; yet, conditions afford strong indications, at least, of the suggestion of the presence of certain physical factors, of marked importance.[1] In support of this statement, the author has critically examined all available authentic analyses of the decayed rock products, and carefully noted each writer's description as to color. One or two illustrations will suffice: Dr. Merrill has described the weathering of a micaceous gneiss from Albemarle county, Virginia, the decayed product (residual soil) of which, he characterizes as "highly plastic" and "deep-red brown" in color, yielding on chemical analysis 12.18 per cent. of Fe_2O_3.[2] The writer (Watson) has described, elsewhere, in this report the changes incident to the weathering of an even-grained granite, near Greenville, Meriwether county, Georgia, the accompanying residual product from which is a highly ferruginous, dark-red, stiff, plastic clay, slightly gritty, chiefly from free quartz, and yielding, on chemical analysis, only 6.33 per cent. of Fe_2O_3. Still another case in question, is the weathering of a similar fine- and even-grained granite near Newnan, Georgia. In this case, the residual product is a clayey mass, less plastic, and not so dark in color as the Greenville material, but a bright red. It yields only 1.91 per cent. of Fe_2O_3, on analysis. Numerous cases among the basic rocks might be cited, and comparisons made with the acid ones; but it is unnecessary; since close study discloses, practically the same results. According to these data, we apparently have residual products of essentially the same character and depth of color, but varying, evidently, in the amount of coloring matter (ferric oxide) present.

[1] The writer is engaged at present in a study of *quantity* of pigment, as bearing on depth of color in soils, which will appear as a future paper.

[2] Bull., Geol. Soc. Amer., 1897, Vol. VIII, pp. 157-168.

The two extremes are represented by 12.18 and 1.91 per cent., respectively, the former containing more than six times the amount of ferric oxide shown in the latter; and yet, the same results, as regards color, are seemingly produced.

Apparent exceptions to the above, however, are found in two sections of fresh and decayed granite, described in Chapter V, Part 2, of this report. The first one is that of the Greenville granite quarry, where a 30-foot vertical section may be seen passing from the heavy, dark-red, plastic clay at the top, through lighter-colored and more modest hues, into fresh, gray rock at the bottom. Chemical analyses gave the following percentages of iron oxide, in specimens of the fresh and decayed granite, taken, at various depths, along the section: Fresh rock, 1.96 per cent.; decayed rock, 10 feet from surface, 4.69 per cent.; and decayed rock, 5 feet from surface, 6.33 per cent. A similar increase in the amount of Fe_2O_3 and depth of coloring, in the change from fresh rock to the most advanced stage in the decomposition of the granite, is observed in the Cole quarry, near Newnan, Georgia. The range in iron oxide at this quarry is: Fresh rock, 1.41 per cent.; decayed granite, 10 feet below the surface, 1.74 per cent.; decayed rock, 5 feet below the surface, 1.91 per cent.

Calculated Percentage Amounts, Saved and Lost, per Each Constituent, Based on the Assumption of an Al_2O_3 and an $Al_2O_3+Fe_2O_3$ Constant Basis

Of the essential constituents, occurring in appreciable quantities in siliceous crystalline rocks, the iron and aluminum oxides prove the most refractory; and they are, therefore, the least likely to suffer loss, during the processes of rock degeneration—weathering. While the results are not absolutely confirmatory, the work of Dunnington,[1] Clarke[2] and Smyth,[3] strongly indicates concentration, instead of loss in titanium in the residual product, derived from the titanium bearing minerals, upon weathering. This element occurs, however, so sparingly distributed through a majority of the crystalline rocks, usually averaging less than 0.5 of one per cent., that it cannot be regarded as a safe basis of assumption for calculating the percentage amounts of the more essential constituents, saved and lost, that are present in the rock. It may, when present, be used (added to) with one of the more refractory essential constituents, iron or aluminum oxides, as a basis for calculation,

[1] Amer. Jour. Sci., (3rd S.) Vol. XLI, pp. 491-495.

[2] Bull. No. 78, U. S. Geol. Surv., pp. 34-42.

[3] Bull., Geol. Soc. Amer., 1898, Vol. IX, pp. 257-269.

thereby lessening, perhaps, the possible error resulting from computations based on the assumption of only one constant constituent. Smyth,[1] by assuming the $TiO_2+Al_2O_3$ to be constant, illustrates the above use of TiO_2 in the weathering of Alnoite, at Manheim, New York.

Since iron and alumina occur, as essential constituents, in all ferro-magnesian-feldspathic-silicate rocks, and have proved to be the most refractory of the essential elements towards weathering agencies; one or the other, according to the increased ratio, in the decayed over the fresh rock, forms the most reliable basis on assumption, for calculating the amounts, lost and saved, of the other constituents present.

In the case of the Georgia granitic rocks, the iron and aluminum oxides, have proved the most resistant of the constituents present toward the weathering agents; and, while the ratio of increase for the two is nearly the same, that of the iron is, with several exceptions, slightly greater than that of the alumina; and it has, therefore, been assumed to remain constant, for convenience of comparison of the analyses of the fresh and decayed rock in tables I, II, V, VI, VIII and IX, on pages 302, 306, 315, 318, 325 and 327.

A perusal of the figures in the above tables, however, discloses the fact, that the percentage of iron oxide in the fresh and decayed rock is very small—strikingly smaller than that of the alumina. Recalculation, based on some constituent present in small percentage amount, often results in multiplying the possible errors, and may be at variance with the true results. While the ratio of increase in the iron oxide, as pointed out above, is slightly greater than that of the alumina for the decayed and the fresh rock, the writer has recalculated all the results in a similar manner: First, on the assumption of an Al_2O_3 constant basis; and second, on the assumption of an $Al_2O_3+Fe_2O_3$ constant basis, for the sake of diminishing the possible error, resulting from a ratio obtained from too small percentage amounts, of the constituent assumed constant, Fe_2O_3; also, for the purpose of making comparisons and pointing out the possible differences resulting. Whatever constituent is assumed to remain constant, the results must be taken at best as only approximate; for there are many chances of possible errors, the principal of which are, first, more or less variation in mineral composition of the rock, within very short range, necessarily causing a corresponding variation in chemical composition; second, variation, dependent upon analytical methods, and the degree of

[1] Bull., Geol. Soc. Amer., 1898, Vol IX, pp. 262–263.

accuracy and proficiency of the analyst, when given a perfectly homogeneous and non-varying rock in composition; and third, the method and accuracy used in sampling, which is particularly applicable to the residual product. Other possible sources of error will become apparent, in a perusal of the tables, which follow below.

ASSUMPTION OF AN Al_2O_3 CONSTANT FACTOR

The percentage amount of alumina is greater, in every case of the Georgia granites, for the decayed product, than for the corresponding fresh rock; and is present in larger amounts than any other single constituent, where increase in the decayed over the fresh rock is indicated.

To avoid repetition, the analyses of the fresh and decayed rock are omitted from the tables given below. When desired, convenient reference may readily be made to the original tables.

TABLE I

Constituents	Calculated Percentage Amounts, Saved and Lost, Columns 4 and 5			Calculated Percentage Amounts, Saved and Lost, Columns 4 and 6		
	Saved	Lost	Entire Rock	Saved	Lost	Entire Rock
SiO_2 . . .	62.82	37.18	25.70	93.09	6.91	4.77
CaO . . .	1.50	98.50	1.88	49.00	51.00	0.97
MgO . . .	84.00	16.00	0.06	86.48	13.52	0.04
Na_2O . . .	32.38	67.62	3.24	70.43	29.57	1.41
K_2O . . .	48.16	51.84	2.74	97.47	2.53	0.13
Total . .			33.62			7.32

Factor, 1.39. Factor, 1.05.

Fe_2O_3 and H_2O (ignition) indicate gains.

TABLE II

Constituents	Saved	Lost	Entire Rock
SiO_2	93.87	6.13	4.25
CaO	43.89	56.11	1.36
MgO	32.14	67.86	0.35
Na_2O	86.60	13.40	0.63
K_2O	77.89	22.11	1.18
Total			7.77

Factor, 1.08.

Fe_2O_3 and H_2O (ignition) indicate slight gains.

In tables III, IV, VII and X, the Al_2O_3 shows the largest ratio of increase; and it has accordingly been assumed to remain constant, as a basis for calculating the amounts, saved and lost, of the other constituents.

TABLE V

Constituents	Calculated Percentage Amounts, Saved and Lost, Columns 4 and 5			Calculated Percentage Amounts, Saved and Lost, Columns 4 and 6		
	Saved	Lost	Entire Rock	Saved	Lost	Entire Rock
SiO_2 . . .	49.56	50.44	34.94	40.69	59.31	41.08
CaO	1.79	98.21	1.73	2.18	97.82	1.73
MgO . . .	37.50	62.50	0.22	21.53	78.47	0.28
Na_2O . . .	30.80	69.20	3.05	14.00	86.00	3.80
K_2O . . .	32.34	67.66	3.77	14.76	85.24	4.75
Total . .			43.71			51.64

Factor, 1.58. Factor, 1.81.

Fe_2O_3 and H_2O (ignition) indicate a gain in each case.

TABLE VI

Constituents	Saved	Lost	Entire Rock
SiO_2	92.38	7.62	5.31
CaO	97.84	2.16	0.05
MgO	76.69	23.31	0.23
Total			5.59

Factor, 1.05.

Na_2O and K_2O indicate very slight gains. Fe_2O_3 and H_2O (ignition) also indicate slight gains.

TABLE VIII

Constituents	Saved	Lost	Entire Rock
SiO_2	65.77	34.23	21.60
CaO	4.02	95.98	3.11
MgO	75.12	24.88	0.37
Na_2O	30.88	69.12	3.25
K_2O	65.76	34.24	1.55
Total			29.88

Factor, 1.30.

Fe_2O_3 and H_2O (ignition) indicate gains.

TABLE IX

Constituents	Saved	Lost	Entire Rock
SiO_2	76.88	23.12	17.52
CaO	22.65	77.35	0.81
MgO	31.25	68.75	0.18
Na_2O	58.89	41.11	1.59
K_2O	78.59	21.41	1.00
Total			21.10

Factor, 1.22.
Fe_2O_3 and H_2O (ignition) indicate gains.

ASSUMPTION OF AN $Al_2O_3 + Fe_2O_3$ CONSTANT FACTOR

In the same way, as is indicated in the assumptive iron and alumina constant factors, the percentages of Al_2O_3 and Fe_2O_3 have been added together for both the fresh and the decayed rock; and the ratio of increase in the decayed over the fresh material is assumed as a constant, for reckoning the amounts, saved and lost, of each of the other constituents.

TABLE I

Constituents	Fresh Rock	Decayed Rock	Difference	Fresh Rock	Decayed Rock	Difference
Fe_2O_3	1.44	2.42	0.98	1.44	1.52	0.08
Al_2O_3	16.58	23.08	6.50	16.58	17.47	0.89

Constituents	Calculated Amounts, Saved and Lost, Columns 4 and 5			Calculated Amounts, Saved and Lost, Columns 4 and 6		
	Saved	Lost	Entire Rock	Saved	Lost	Entire Rock
SiO_2	61.92	38.08	26.33	93.09	6.91	4.77
CaO	1.48	98.52	1.88	49.00	51.00	0.97
MgO	84.00	16.00	0.05	86.48	13.52	0.04
Na_2O	31.95	68.05	3.26	70.43	29.57	1.41
K_2O	47.51	52.49	2.77	97.47	2.53	0.13
Total			34.29			7.32

Factor, 1.41. Factor, 1.05.
H_2O (ignition) indicates a gain.

TABLE II

Constituents	Fresh Rock	Decayed Rock	Difference
Fe_2O_3	1.30	1.52	0.22
Al_2O_3	15.47	16.80	1.33

Constituents	Saved	Lost	Entire Rock
SiO_2	93.03	6.97	4.83
CaO	43.56	56.44	1.37
MgO	32.14	67.86	0.36
Na_2O	85.93	14.07	0.67
K_2O	77.09	22.91	1.23
Total			8.46

Factor, 1.09.

Table III shows the same amounts of the constituents, saved and lost, on an $Al_2O_3 + Fe_2O_3$ basis, as on an Al_2O_3 constant one, for the reason that the percentage of iron oxide in the fresh and the decayed rock is the same — 1.32 per cent. Fe_2O_3. The total percentage loss for the rock is the same for the two assumed constants ($Al_2O_3 + Fe_2O_3$ and Al_2O_3), with the exception that a loss occurs in the iron constituent in the case of the Al_2O_3 constant, which does not occur in the $Al_2O_3 + Fe_2O_3$ constant. This difference is shown in the table on page 348.

TABLE IV

Constituents	Fresh Rock	Decayed Rock	Difference
Fe_2O_3	1.40	1.91	0.51
Al_2O_3	17.59	26.04	8.45

Constituents	Saved	Lost	Entire Rock
SiO_2	56.44	43.56	29.94
CaO	15.72	84.28	2.74
MgO	18.08	81.92	0.52
Na_2O	28.63	71.37	3.24
K_2O	50.20	49.80	1.62
Total			38.06

Factor, 1.47.
H_2O (ignition) indicates a gain.

TABLE V

Constituents	Fresh Rock	Decayed Rock	Difference	Fresh Rock	Decayed Rock	Difference
Fe_2O_3 . . .	1.95	4.66	2.71	1.95	6.30	4.35
Al_2O_3 . . .	16.28	25.75	9.47	16.28	29.54	13.26

Constituents	Columns 4 and 5			Columns 4 and 6		
	Saved	Lost	Entire Rock	Saved	Lost	Entire Rock
SiO_2 . . .	47.17	52.83	36.60	37.58	62.42	43.24
CaO	1.70	98.30	1.74	7.98	97.98	1.73
MgO . . .	35.59	64.41	0.23	20.00	80.00	0.28
Na_2O . . .	29.33	70.67	3.12	12.93	87.07	3.84
K_2O . . .	31.30	69.23	3.86	13.63	86.37	4.81
Total . .			45.54			53.90

Factor, 1.66. Factor, 1.96.

H_2O (ignition) indicates a gain.

TABLE VI

Constituents	Fresh Rock	Decayed Rock	Difference
Fe_2O_3	1.60	1.90	0.30
Al_2O_3	17.03	18.01	0.98

Constituents	Saved	Lost	Entire Rock
SiO_2	90.66	9.34	6.51
CaO	96.18	3.82	0.08
MgO	75.23	24.77	0.24
Total			6.63

Factor, 1.07.

H_2O (ignition) indicates a gain.

Na_2O and K_2O indicate very slight gains.

In table VII, the factor is the same for the two assumed constants, $Al_2O_3+Fe_2O_3$ and Al_2O_3. The factor in each case is 1.39; hence, the percentage amounts, saved and lost, per each constituent, are the same, except in the case of the Fe_2O_3, which indicates a loss on the Al_2O_3 basis, not shown in the $Al_2O_3+Fe_2O_3$ constant. The total percentage amounts lost, for the entire rock, on the two assumed constants, are given in the table on page 348, and the figures need not be repeated here.

TABLE VIII

Constituents	Fresh Rock	Decayed Rock	Difference
Fe_2O_3	2.18	3.09	0.91
Al_2O_3	20.29	26.46	6.17

Constituents	Saved	Lost	Entire Rock
SiO_2	65.27	34.73	21.92
CaO	4.00	96.00	3.12
MgO	74.35	25.65	0.38
Na_2O	30.63	69.37	3.26
K_2O	65.31	34.69	1.57
Total			30.25

Factor, 1.31.
H_2O (ignition) indicates a gain.

TABLE IX

Constituents	Fresh Rock	Decayed Rock	Difference
Fe_2O_3	0.92	1.21	0.39
Al_2O_3	13.08	16.02	2.94

Constituents	Saved	Lost	Entire Rock
SiO_2	76.26	23.74	17.99
CaO	22.48	77.52	0.81
MgO	30.30	69.70	0.18
Na_2O	58.40	41.60	1.60
K_2O	77.91	22.09	1.03
Total			21.61

Factor, 1.23.
H_2O (ignition) indicates a gain.

TABLE X

Constituents	Fresh Rock	Decayed Rock	Difference
Fe_2O_3	1.10	1.21	0.11
Al_2O_3	13.94	14.77	0.83

TABLE X—Continued

Constituents	Saved	Lost	Entire Rock
SiO_2	91.81	8.19	6.11
CaO	41.12	58.88	0.69
MgO	22.22	77.78	0.13
Na_2O	81.54	18.46	0.74
K_2O	Indicates a very slight gain.		
Total			7.67

Factor, 1.23.
H_2O (ignition) indicates a gain.

Résumé

Briefly stated, a comparative study of the above tables, based on the assumption of first an Al_2O_3, and next, an $Al_2O_3 + Fe_2O_3$ constant, shows: (1) That, on the assumption of an Al_2O_3 constant, the Fe_2O_3, like the H_2O, indicates a slight gain, owing to the ratio of increase being greater for the iron oxide, than for the Al_2O_3. (2) That the calculated percentage amounts of the constituents, saved and lost, are in similar ratios for the three cases, but differ in actual amounts in each one. The constituent, showing the greatest loss under one assumed constant, likewise indicates similar loss for the other two assumptions. The percentage amount, lost or saved, for any one constituent, is not the same in the three cases. (3) That the total percentage loss for the entire rock is invariably greater, on the assumption of an Fe_2O_3 constant, than for the other two assumed constants. In each case, it will be observed, that the lime salts have been removed, in larger amounts than the magnesia; and, similarly, the soda has suffered a greater loss than the potash. The fact, particularly emphasized here, is the greater loss for the entire rock, with one or two exceptions, on the Fe_2O_3 assumed constant over that of the Al_2O_3 and $Al_2O_3 + Fe_2O_3$ assumptions. As may be seen from the tables, the conclusions stated, under (2) and (3), are governed directly by the numerical value of the ratio of increase (factor) of the constituent, assumed to remain constant, in the change from fresh to residual rock.

The loss for the entire rock, based on the three assumptive insoluble constituents, are tabulated below for convenience of comparison:—

	Fe_2O_3 Constant	Al_2O_3 Constant	Fe_2O_3 $+Al_2O_3$ Constant
Table I	{ 7.71 } { 44.72 }	{ 7.32 } { 33.62 }	{ 7.32 } { 34.29 }
Table II	14.56	7.77	8.46
Table III	——	7.92	7.84
Table IV	34.59	38.48	38.06
Table V	{ 61.98 } { 71.82 }	{ 43 71 } { 51.64 }	{ 45.54 } { 53.90 }
Table VI	15.84	5.59	6.63
Table VII	33.00	34.04	34.00
Table VIII	35.07	29.88	30.25
Table IX	26.69	21.10	21.61
Table X	10.46	7.61	7.67

CHAPTER VI

STATISTICS, PHYSICAL TESTS AND CHEMICAL ANALYSES

I. Statistics

The following figures show the value of the Georgia granite product, by years, from 1887 to 1899 inclusive :—[1]

1887	$ 400,000
1888	467,000
1889	752,481
1890	752,481
1891	790,000
1892	700,000
1893	467,387
1894	511,804
1895	508,481
1896	274,734
1897	436,000
1898	339,311
1899	411,344

The Tenth Census, in 1880, placed Georgia as the twelfth granite-producing State in the Union. The value of the granite-product in the State, for that year, was estimated at $64,480. The next decade, ending 1890, witnessed a remarkable growth in, and development of, the granite industry in the State, revealed in the enormous increase in production. The rapid advancement, made during this period, is shown in the Eleventh Census report for 1890, where Georgia is ranked as sixth among the granite-producing States. The valuation of the granite production by States, for 1889, placed Georgia ahead of New Hampshire, which has long been known as the "Granite State." The order in production by States, for 1889, was: Massachusetts, Maine, California, Connecticut, Rhode Island, Georgia and New Hampshire. Named in the order of their importance, the granite-producing counties in the State, for that year, are as follows: DeKalb, $606,075; Hancock, $68,083; Henry, $57,950; with smaller amounts from Bibb, Elbert, Spalding, Rockdale, Jones, Oglethorpe and Newton. The

[1] Min. Resources of the U. S., 1887 to 1890, incl., U. S. G. S.
Twenty-first Ann. Rept., U. S. G. S., 1899–1900, Part VI, pp. 339–340.

product for 1889 was proportioned as follows: Building purposes, $347,100; street work, more than $250,000; while the residue was used for cemetery, bridge and railroad purposes.

The greater part of the product for 1887, valued at $400,000, was used in the form of paving-blocks, curbing and flagging, and was shipped to the Southern and Western States, generally. The following figures show the annual value of paving-blocks, quarried from the Georgia granite, from 1894 to 1899 inclusive:—[1]

1894	$ 225,910
1895	232,041
1896	94,390
1897	295,005
1898	92,550
1899	37,500

VALUE OF THE GRANITE PRODUCTION IN GEORGIA BY YEARS, AND ITS USES

	1896 [2]	1897 [3]	1898 [4]	1899 [5]
Sold in Rough State	$ 29,127	$ 40,288	$ 38,255	$ 69,370
Building Purposes	64,093	56,366	67,909	185,135
Monumental and Cemetery Purposes	11,900	15,083	21,775	13,227
Paving-blocks	94,390	295,005	92,550	37,500
Macadamizing Purposes	11,634	2,318	32,500	30,564
Curbing	63,590	26,940	67,492	68,748
Riprap		——	18,830	6,800
Total	$274,734	$436,000	$339,311	$411,344

From the above figures, it will be observed, that Georgia has already taken high rank among the granite-producing States in the United States; and, from the beginning, it has been the foremost one among the Southern States, in point of production. From the great abundance and variety of easily quarried granite, of excellent quality, in the State, well suited to the various grades of work, to which this rock is usually put, ordinary prosperity in general business must unquestionably result in making the granite industry in Georgia a most important one, in the course of a few years.

Owing, therefore, to the cheapness of labor; the ease and readiness, with which the stone can be quarried; the ready accessibility, and the enormous quantity and variety of granite within the limits of the State, Georgia has already become a strong com-

[1] 16th Ann. Rept., U. S. G. S., 1894–'95, Part IV, p. 457.
18th Ann. Rept., U. S. G. S., 1896–'97, Part V, p. 956.
21st Ann. Rept., U. S. G. S., 1899–1900, Part VI, p. 338.

[2] 18th Ann. Rept., U. S. G. S., 1896–'97, Part V, p. 956.

[3] 19th Ann. Rept., U. S. G. S., 1897–'98, Part VI, p. 209.

[4] 20th Ann. Rept., U. S. G. S., 1898–'99, Part VI, pp. 272-273.

[5] 21st Ann. Rept., U. S. G. S., 1899–1900, Part VI, p. 337.

petitor with the leading granite-producing sections of New England, in many parts of the United States.

II. PHYSICAL TESTS

Specific Gravity, Ratio of Absorption, Weight per Cubic Foot, and Number of Cubic Feet Contained in 1 Ton (2,000 lbs.)

GRANITE

Name of Quarry	Specific Gravity	Ratio of Absorption	Weight Per Cubic Foot	Number Cubic Feet Stone in 2,000 Pounds
Lexington Blue Granite Company	2.666	0.092	166.25	12.0
Diamond Blue Granite Company .	2.666	0.088	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 Company . .	2.662	0.086	166.37	12.0
Swift and Wilcox Quarry	2.652	0.090	165.75	12.0
" " " Flat Rock . . .	2 645	0.092	165.31	12.0
Tate and Oliver	2.670	0.093	166.87	11.9
Coggins	2.840	0.090	177.50	10.7
Bisson	2.664	——	166 50	12.0
Deadwyler (Collins and Venable) .	2.662	——	166.37	12.0
Childs	2.665	0.092	166.56	12.0
Carmichael	2.658	——	166.12	12.0
Linch	2.701	0.060	168.81	11.8
Stone Mountain	2.686	0.067	167.90	11.9

PORPHYRITIC GRANITE

Name of Quarry	Specific Gravity	Ratio of Absorption	Weight per Cubic Foot	Number Cubic Feet 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	——	0.049	——	——
Heggie-Rock, Columbia County .	2.674	——	166.87	11.9
A. J. McElwaney, Fayette County	2.659	——	166.18	12.0

GRANITE-GNEISS

Name of Quarry	Specific Gravity	Ratio of Absorption	Weight Per Cubic Foot	Number Cubic Feet Stone in 2,000 Pounds
Odessa	2.642	0.056	165.12	12.1
Snell	2.642	0.075	165.12	12.1
Tilly	2.643	——	165.18	12.1
Lithonia	2.686	0.052	167.90	11.9
Flat Rock, Heard County	2.648	——	165.50	12.0
Arabia Mountain, Lithonia . . .	——	0.050	——	——

CRUSHING TESTS FOR STRENGTH

The following tests, on specimens of Stone Mountain granite and contorted Lithonia granite-gneiss, were made in 1887 at the Washington Navy-Yard :—[1]

Locality	Dimensions	Crushed at Pounds	Remarks
Lithonia . . .	2.00 in. x 2.00 in. x 2.02 in.	76,000	
"	2.00 " x 2.01 " x 2.00 "	83,400	
" (No. 3).	2.06 " x 2.06 " x 2.09 "	52,650	
"	2.01 " x 2.01 " x 2.01 "	———	Did not crush at 85,000 lbs. pressure.
"	2.00 " x 1.98 " x 1.98 "	———	Did not crush at 85,000 lbs. pressure.
Stone Mountain	2.05 " x 2.00 " x 2.01 "	———	Did not crush at 85,000 lbs. pressure.
" "	1.99 " x 1.99 " x 2.00 "	50,325	
" "	1.99 " x 1.99 " x 2.00 "	48,760	
" "	2.02 " x 2.02 " x 2.03 "	65,610	

The following table gives the results of tests, made at Purdue University, LaFayette, Ind., on specimens of stone, from the same locality :—[2]

Locality	Dimensions	Crushed at Pounds	Crushed at Lbs. per Sq. Inch
Lithonia . . .	2.02 in. x 2.04 in. x 2.07 in.	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
" . . .	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
Stone Mountain	2.00 " x 2.01 " x 2.02 "	50,000	12,438
" "	1.99 " x 2.01 " x 1.99 "	57,700	14,425
" "	2.04 " x 2.04 " x 2.05 "	53,700	12,904
" "	2.04 " x 2.07 " x 2.05 "	55,700	13,190
" "	2.01 " x 2.03 " x 2.02 "	54,700	13,406
" "	2.02 " x 2.05 " x 2.01 "	52,700	12,726

[1] Granite Pavements; Compiled by Venable Brothers, Atlanta, Ga., 1893.
[2] *Ibid.*

Another series of tests, made on the Stone Mountain granite at the Watertown Arsenal, under the direction of Major J. W. Reilly, U. S. A., gave 25,630 and 28,130 pounds per square inch on the bed. For Lithonia Stone, they gave 30,320; 28,290 and 28,250 pounds per square inch on the bed. An average of six tests, made on the Lithonia stone by Mr. John Bradley, gave 31,816 pounds per square inch.

The following tests were made at the Watertown Arsenal in 1894 on specimens of the Diamond Blue Granite Company's granite, near Hutchins, Oglethorpe county:—[1]

Test Number	How Tested	Size	Pressure per Square Inch in Pounds
7304	On Bed . .	3.07 in. x 3.06 in. x 3.04 in.	26,340
7307	On Grain. .	3.16 " x 2.99 " x 3.10 "	23,860

[1] 18th Ann. Rept., U. S. G. S., 1896–'97, Part V, pp. 990–991.

III. Chemical Analyses

The chemical analyses of the Georgia granites, both fresh and decayed rock, made by the writer in the laboratory of the Geological Survey, are grouped in tabular form on the succeeding pages. They have been discussed at some length elsewhere in this report. The analyses of the fresh rock are grouped under the headings, Granite, Porphyritic Granite and Granite-Gneiss. Those, of the weathered rocks, are given in one table on page 356.

GRANITE

Name of Quarry	Silica	Alumina	Iron Sesqui-Oxide	Lime	Magnesia	Potash	Soda	Ignition	Total
Henry Pettus, Wilkes County	74.64	14.00	1.05	1.76	0.37	7.77[1]		0.41	100.00
Stone Mountain (No. 1)	72.56	14.81	0.94	1.19	0.20	5.30	4.94	0.70	100.64
Stone Mountain (No. 2)	71.66	16.05	0.86	1.07	0.17	4.92	4.66	1.00	100.39
Fortson	71.00	16.33	1.12	1.83	0.35	4.65	4.80	0.87	100.95
Swift & Etheridge	70.38	16.47	1.17	1.72	0.31	5.62	4.98	0.31	100.96
Diamond Blue Granite Company (Main Opening)	70.30	16.17	1.19	2.61	0.31	4.88	4.72	0.63	100.81
Brown and Deadwyler	70.18	17.30	1.20	2.03	0.64	4.77	4.36	0.35	100.83
Lexington Blue Granite Company	70.03	15.62	1.31	2.45	0.52	5.42	4.82	0.77	100.94
Greenville Granite Company	69.88	16.42	1.96	1.78	0.36	5.63	4.45	0.39	100.87
Coggins	69.74	16.72	1.45	1.93	0.36	5.33	4.84	0.47	100.84
Hill (Coggins Granite Co.)	69.64	17.21	1.32	2.14	0.66	4.95	4.53	0.35	100.80
Carmichael, Campbell County	69.55	16.72	0.99	1.69	0.27	3.94	5.88	0.27	99.31
Diamond Blue Granite Company (Average from Minor Openings)	69.53	16.46	1.15	2.10	0.85	4.91	5.00	0.91	100.91
Swift and Wilcox, Elbert county	69.45	15.93	1.31	1.91	0.55	5.16	4.33	0.50	99.14
Childs, Elbert County	69.36	17.23	1.43	2.14	0.59	4.57	5.17	0.33	100.82
Linch, Putnam County	69.34	17.01	1.74	2.77	0.61	4.54	4.69	0.26	100.96
Tate and Oliver, Elbert County	69.25	16.04	1.72	1.89	0.31	4.94	4.52	0.43	99.10
R. D. Cole, Coweta County	69.08	17.67	1.41	3.27	0.64	3.29	4.56	0.56	100.48
Overby, " "	69.07	16.56	1.37	1.83	0.76	5.02	4.65	0.92	100.18
Echols Mill, Oglethorpe County	68.81	17.67	1.13	2.17	0.50	3.90	4.97	0.30	99.45
Sam Hill, Coweta County	68.79	16.48	0.98	1.76	1.30	5.85	4.74	0.38	100.28
Turner, Spalding County	68.76	16.80	0.99	2.72	1.00	3.70	4.82	0.29	99.08
Forty-foot Dike, near Camak	68.38	17.79	1.21	2.85	0.72	3.57	4.36	0.78	99.66
Moreland, Coweta County	66.92	18.19	3.05	4.95	1.25	2.02	3.83	0.46	100.67
T. B. Tigner, Meriwether County	63.27	19.93	2.82	2.89	0.49	4.85	4.14	0.86	99.25
A. M. Hill, " "	62.52	23.58		3.24	1.55	8.57[1]		0.54	100.00

[1] By difference.

PORPHYRITIC GRANITE

Name of Quarry	Silica	Alumina	Iron Sesqui-Oxide	Lime	Magnesia	Potash	Soda	Ignition	Total
Georgia Quincy Granite Company	70.90	15.86	1.37	2.15	0.02	4.62	5.05	0.50	100.47
A. J. McElwaney, Fayette County	70.88	15.86	1.77	1.79	0.93	4.64	3.94	0.49	100.30
Flat Rock, Pike County	70.24	16.78	1.46	2.00	0.76	5.03	3.70	0.50	100.47
Heggie-Rock, Columbia County	69.77	17.05	1.60	2.21	0.99	4.08	3.97	0.44	100.11
Mallally, Hancock County	69.48	16.64	1.84	2.32	0.29	4.49	4.74	0.46	100.26
L. N. Calloway, Baldwin County	69.37	16.99	1.99	2.03	0.84	4.54	3.44	0.55	99.75
Moseley, Fulton County	69.17	16.47	1.22	2.02	0.61	4.41	4.89	1.06	99.85
Ten Miles South of Greensboro, Greene County	69.13	17.14	1.52	1.85	0.79	5.49	4.06	0.52	100.50
Charley Rocker, Hancock County	67.62	16.29	2.31	2.37	0.78	4.58	5.42	0.32	99.69
Brinkley Place, Warren County	66.31	18.27	2.51	2.91	1.22	4.09	3.69	0.61	99.61
McCollum, Coweta County	63.65	20.46	2.20	3.38	1.50	4.58	4.75	0.42	100.94
Feldspar Phenocrysts, Heggie-Rock	64.64	19.64	0.37	0.67	trace	10.00	3.06	0.22	98.60
" " McCollum Quarry . . .	64.40	18.97	0.37	0.59	trace	11.40	3.60	0.19	99.52
" " " (Decay) . .	59.70	21.73	0.60	0.04	trace	13.80	2.09	3.00	100.96

GRANITE-GNEISS

Name of Quarry	Silica	Alumina	Iron Sesqui-Oxide	Lime	Magnesia	Potash	Soda	Ignition	Total
Odessa, Meriwether County.	76.37	13.31	1.21	1.13	0.10	3.68	4.02	0.20	100.02
Crossley, near Lithonia, DeKalb County . . .	76.00	13.11	0.92	1.06	0.27	4.69	3.88	0.31	100.24
Snell, Gwinnett County	75.89	14.02	0.71	0.70	0.12	5.56	3.64	0.28	100.92
Tilley, Rockdale County	75.45	13.71	0.92	0.94	0.18	4.30	3.87	0.40	99.77
Arabia Mountain, DeKalb County	75.16	13.74	0.91	0.91	0.17	5.05	3.76	0.32	100.02
Flat Rock, Heard County[1]	74.96	13.71	0.90	1.02	0.24	4.79	4.68	0.44	100.74
Flat Shoals, Meriwether County[1]	74.80	15.46	1.04	0.82	0.11	2.52	4.80	0.31	99.86
Flat Rock, Coweta County	73.95	14.23	1.29	1.07	0.23	5.29	4.61	0.25	100.92
Southern Granite Company	72.96	14.70	1.28	1.28	0.07	4.73	4.18	0.23	99.43
Freeman, Newton County	71.20	15.46	1.17	1.36	0.38	5.30	4.96	0.52	100.35
Athens, Clarke County	69.51	16.32	2.38	1.84	1.28	3.47	3.82	1.11	99.73
McElvaney Shoals, Gwinnett County	68.89	16.47	2.34	1.63	0.40	4.15	4.38	0.32	98.58
Milledgeville (Grano-Diorite)	55.47	22.63	3.96	6.62	2.97	2.09	4.59	0.69	99.02

[1] The rock from this locality is a typical foliated granite, and not a true gneiss; but it is so grouped, on structural grounds.

WEATHERED ROCK

Name of Quarry	Silica	Alumina	Iron Sesqui-Oxide	Lime	Magnesia	Potash	Soda	Igni-tion	Total
Southern Granite Company (Granite-Gneiss) .	74.53	13.70	1.15	0.95	trace	5.20	4.41	0.81	100.75
Swift and Wilcox (Decayed Granite, 2 Ft. below Surface)	73.90	13.78	1.23	0.53	0.05	5.43	2.92	2.60	100.44
Crossley, Lithonia, (Granite-Gneiss)	73.48	14.78	1.30	0.31	trace	5.00	3.43	2.42	100.72
" " " "	71.67	16.14	1.22	0.29	0.10	4.52	2.80	4.03	100.77
Lexington Blue Granite (Granite)	70.50	16.84	1.53	1.15	0.18	4.52	4.47	1.06	100.25
Swift and Wilcox (Partially Decayed Granite)	69.00	17.31	1.31	1.18	0.42	4.74	4.00	1.79	99.75
Coggins (Granite)	67.92	17.55	1.53	0.99	0.32	5.43	3.57	3.17	100.48
Heggie-Rock (Porphyritic Granite)	67.87	18.08	1.91	2.28	0.79	4.52	4.32	0.63	100.40
R. D. Cole, 10 Feet below Surface, (Granite) .	61.18	22.80	1.74	3.06	0.34	7.94[1]		2.94	100.00
Peter Bisson (Granite)	60.94	23.29	2.44	0.04	0.43	3.57	2.18	8.03	100.92
J. R. McCollum (Porphyritic Granite)	60.29	22.45	2.53	0.83	0.58	7.84[1]		5.49	100.00
R. D. Cole, 5 Feet below Surface (Granite) . .	56.99	26.02	1.91	0.75	0.17	2.40	1.91	9.76	99.91
Brinkley Place (Porphyritic Granite)	56.40	25.62	3.45	0.37	0.98	2.99	1.36	9.18	100 35
Greenville Granite Company (Granite)	54.57	25.90	4.69	0.05	0.21	2.87	2.16	10.14	100.59
J. R. McCollum, Railway Cut (Porphyritic Granite)	53.58	26.27	3.07	0.17	1.44	3.85	1.88	9.02	99.28
Greenville Granite Company (Granite)	51.29	29.69	6.33	0.07	0.14	1.50	1.12	10.36	100.50
" " " (Griffin-Greenville wagon-road)	48.35	28.03	4.75	3.97	3.45	5.35[1]		6.10	100.00

PARTIAL ANALYSES OF EXTRACT FROM DIGESTION OF FRESH ROCK IN HALF-NORMAL HYDROCHLORIC ACID

Name of Quarry	Alumina and Iron	Lime	Magnesia	Potash	Soda
Diamond Blue Granite Company (Granite)	4.23	0.54	trace	1.09	0.64
Coggins (Granite)	4.05	0.53	trace	1.07	0.57
Swift and Wilcox (Granite).	3.69	0.26	trace	1.02	0.29
Echols Mill (Granite)	2.75	0.93	trace	0.99	0.30

[1] By difference.

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