GEOLOGICAL SURVEY OF GEORGIA

S. W. McCALLIE, State Geologist

BULLETIN No. 27

A REPORT

ON THE

LIMESTONES AND CEMENT MATERIALS

OF

NORTH GEORGIA

BY

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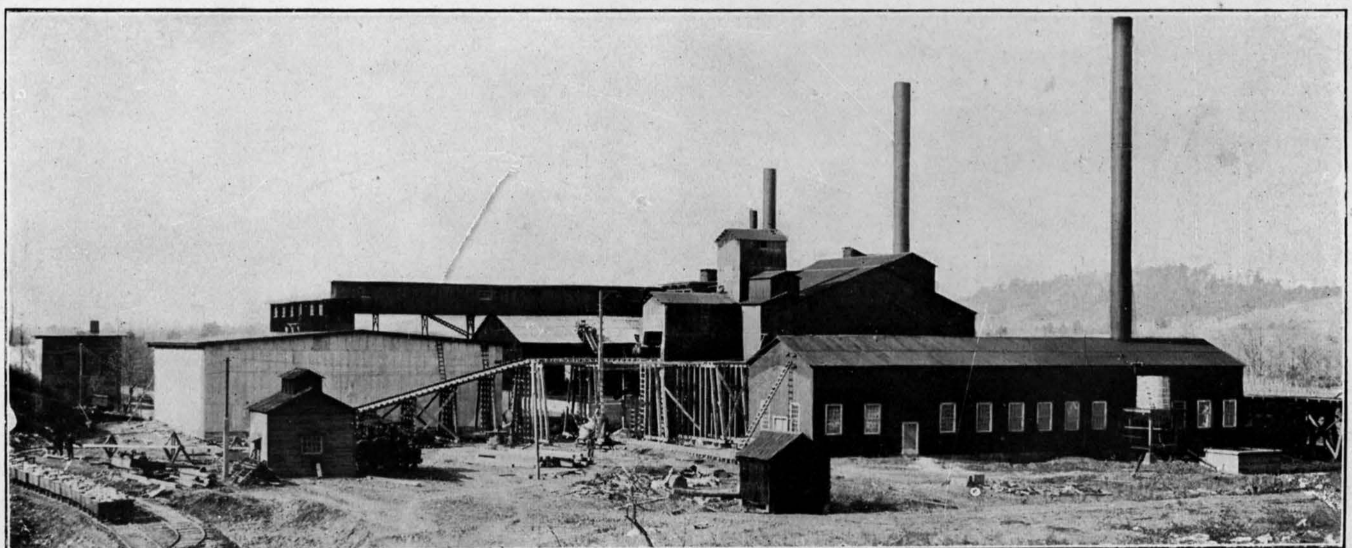

PLANT OF THE PIEDMONT PORTLAND CEMENT COMPANY, POLK COUNTY, GEORGIA

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GEOLOGICAL SURVEY OF GEORGIA,

ATLANTA, August 26, 1912.

To His Excellency, JOSEPH M. BROWN, *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. T. Poole Maynard, formerly assistant State geologist of this Survey, on the Limestones and Cement Materials of North Georgia to be published as Bulletin No. 27 of this Survey.

Very respectfully yours,

S. W. MCCALLIE,

State Geologist.

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PREFACE

The writer desires to present in this report the results of his researches on the lime and cement materials of North Georgia, and after careful consideration of all the conditions pertaining to their commercial development to make known for what purposes these materials can best be used.

All the literature at the writer's command has been made use of in preparing that portion of the report which deals with limestones and cements, their manufacture, uses, etc. The geology of the Appalachian Valley and the Cumberland Plateau is discussed in more detail than is usual in an economic report. An intimate knowledge of the geology of this area was essential in order to fully comprehend the possibilities of the undeveloped deposits. Every outcrop of limestone of any commercial importance, together with the associated shales, has been sampled and analyses have been made. Especial care was taken not only to locate definitely on a topographic map the position of the section, but to describe carefuly each lithologic unit, and to show in the sections described the character of the unit corresponding to any analysis.

The maps accompanying this report show the distribution of the lime and cement materials in the Piedmont Plateau, the Appalachian Mountains, the Appalachian Valley, and the Cumberland Plateau, along with the definite location of more than 350 samples which were analyzed by Dr. Edgar Everhart, chemist of the Geological Survey of Georgia.

The discussion of the lime and cement materials by districts or by lesser physiographic and geologic subdivisions is usually preferable to the geologist; however, the description of individual localities by counties makes the information in this report more accessible to the property owners, for which reason this report has been arranged to conform with other reports issued by the Survey.

The writer desires to express his sincere thanks to Prof. S. W. McCallie for many valuable suggestions in the preparation and revision of the manuscript. Dr. Edgar Everhart, chemist of the Geological Survey of Georgia, and Mr. Clarence N. Wiley, general manager of the Atlantic and Gulf Portland Cement Company, have always gladly co-operated and given their advice freely. The writer is also indebted to the general managers and chemists of the Southern cement mills and the lime manufacturers of Georgia for their many courtesies.

LIMESTONE AND CEMENT MATERIALS OF NORTH GEORGIA

LIMESTONE, CLAYS, SHALES AND SLATES

LIMESTONES

ORIGIN

Lime (calcium) occurs originally in the igneous rocks of the earth's crust, where it is found in combination with a great number of substances and is an important constituent in a large number of rock-making minerals. Lime never occurs in nature as such, but always in combination with other constituents as carbonate, sulphate, silicate, phosphate, etc. On account of its ease of combination there are a great number of rock-making minerals containing a large percentage of lime.

By the action of water and the acids of the atmosphere and lithosphere, lime is dissolved. The analyses of river waters show them to contain a considerable amount of carbonic acid. This holds the lime in solution and it is carried by the rivers to the sea where limestones (carbonates of lime with varying amounts of impurities) are formed, either from the accumulation and ultimate consolidation of the fossil remains of organisms which secrete lime or from the chemical precipitation of lime from solution.

The limestones of North Georgia are all of marine origin. They may be divided, for convenience of description, into five distinct types, namely: high-calcium limestones, magnesian limestones, argillaceous limestones, dolomites, and high-calcium or dolomitic marbles. The differences in these calcium and magnesium carbonates are due sometimes to conditions of deposition depending on their origin, either from the accumulation of organic remains, deposition due to chemical precipitation, by the admixture of argillaceous sediments, or to subsequent causes.

PHYSICAL CHARACTER

Limestones show wide differences in physical character. The physical character is usually a criterion of the chemical composition.

Limestones vary in color from pure white to black, depending on differences in chemical composition. The amorphous and semicrystalline limestones are usually light gray to bluish gray in color, or variegated. In the highly crystalline limestones the impurities may be crystallized and segregated in bands or the coloring matter may be uniformly disseminated throughout or irregularly distributed.

Limestones vary in texture from amorphous and semi-crystalline to crystalline. Variation in density and absorption properties are due largely to differences in texture.

Limestones vary in hardness, specific gravity and compactness from the unconsolidated shell marls to the crystalline marbles. Many varieties of limestone are named on the basis of chemical composition, as high-calcium, magnesian, dolomitic, etc. Special names are also given because of their structure or most abundant accessory constituent, as argillaceous, chalky, siliceous, bituminous, oölitic, and pisolitic; and still others are named from certain predominant fossils as crinoidal, coralline, and formaniferal.

CHEMICAL CHARACTER

The chemical composition of a pure limestone is expressed by the formula, $CaCO_3$ (calcium carbonate) or CaO (calcium oxide) 56 per cent. + CO_2 (carbon dioxide) 44 per cent. Limestones seldom occur without the presence of other constituents. Calcium carbonate is the most abundant constituent, and a rock must contain at least 50 per cent. calcium carbonate to be termed a limestone. Silica, magnesia, alumina, the alkalies, etc., occur in less abundance in the limestones and are usually referred to as impurities or accessories. While a very pure limestone is valuable, especially for certain metallurgical and chemical purposes, it is often the accessory constituents or impurities that make the limestone equally as valuable.

The classification of limestones depends largely on their chemical composition. A limestone very high in calcium carbonate with a small percentage of impurities is known as a high-calcium limestone, while limestone containing more than five per cent. of magnesium carbonate is known as a magnesian limestone. When 30 per cent. or more of magnesium carbonate occurs it is known as a dolomite, and when the alumina and silica range from 15 to 20 per cent. the rock is termed an argillaceous limestone. Marble, travertine, calcareous tufa, etc., may have the identical chemical composition of a very pure limestone; however, they are distinguished by their physical properties and not by their chemical composition.

USES OF LIMESTONES AND LIMES

Metallurgical Uses

Lining of furnaces.—Dolomite is used in basic open-hearth furnaces to repair the scorification of the hearth due to the action of the slag.

The furnace structure consists of an outer lining of common brick with an inner permanent lining of magnesite brick, which may be from two to three feet in thickness, and upon this the crushed basic dolomite is tamped. Calcination of the dolomite and the scorification of the hearth, due to the slag, causes the dolomite to be gradually received into the slag and become a part of it, thus adding to the basicity of the slag; however, its assistance is not very great. The stone must be as low in silica, iron and aluminum oxides as possible, so that these acid acting substances will not form sufficient fusible compounds with the bases to lower the refractory properties, and lessen its resistant power to the corrosive action of the furnace burden. The stone for this purpose should approach as closely as possible a theoretical dolomite, so that the content of magnesia may be high. The higher the content of lime the greater the danger of the disintegration of the lining when the furnace is cooled down, as lime oxide slakes readily, while magnesium oxide is more difficult to slake.

Blast furnace flux.—High-calcium limestones and dolomitic limestones or dolomites are used for blast furnace flux In the Pittsburgh district and in the East a high-calcium fluxing stone is extensively used, while in the South dolomite is more generally used as the fluxing stone.

The value of limestones and dolomites for fluxing depends on the quantity of the impurities—silica, alumina, sulphur, and phosphorus—present, and the preference for a limestone or a dolomite depends largely on the chemical composition of the ore used. The function of the fluxing stone is to furnish the bases (lime and magnesia) to combine with the acidic impurities of the ore and coke. As the primary object, therefore, is to flux the acid impurities it is desirable to secure a limestone or dolomite as free from these impurities as possible. Fluxing stones are sometimes used containing as much as 10 per cent. of silica and alumina; however, those in general use run less than 2 per cent. Sulphur and phosphorus are almost always present; however, they occur in such small amounts that they are not considered in estimating the value of a fluxing stone, except in the manufacture of Bessemer iron, in which case the content of phosphorus in the fluxing stone should be less than 0.1 per cent.

The factors determining the character of the fluxing stone most desirable depends on the chemical composition of the ore and the character of the product desired. While limestones possess certain advantages, dolomites also have equal advantages, and, after all, furnace practice in a particular district best determines the character of the fluxing stone to be used.

Following[1] are some of the properties of calcium and magnesium as fluxes:

> The smaller atomic weight of magnesium (40 as compared with 56 for calcium) enables it to combine with a larger proportion of acids than calcium to form a slag of a given formula. For example, $MgSiO_3$ consists of 40 per cent. MgO and 60 per cent. SiO_2; while $CaSiO_3$ consists of 48.28 per cent. CaO and 51.72 per cent. SiO_2. This is almost exactly offset by the smaller percentage of MgO in $MgCO_3$, 47.62 as compared with 56 per cent. CaO in $CaCO_3$. One pound of $MgCO_3$ will convert .2867 pounds of SiO_2 to $MgSiO_3$, whereas one pound of $CaCO_3$ will convert .2896 pounds of SiO_2 to $CaSiO_3$.

[1]Matthews and Grasty, The Limestones of Maryland: Vol. VIII, pt. 3, 1910, p. 240.

Theoretically, a greater quantity of fuel is required to melt a magnesian slag than a lime slag, as the specific heat of magnesia is greater than that of lime. Furnace practice in the Birmingham district, however, indicates that the fuel consumption is not higher. In this district an enormous amount of slag is carried in the furnace, and when lime is used as a flux the furnace "slips" and "hangs," while a magnesia slag is more fluid and the furnace works smooth and regular.

Magnesia is said to have less affinity for sulphur than lime[1]. While the lime may be essential with ores high in sulphur, the hard and soft red hematites of the South are practically free from sulphur and the hard calcareous ores, which constitute the greater portion of the furnace burden, furnish sufficient lime to take care of the sulphur in the coke.

The physical conditions essential for the fluxing stone are: (1) the stone must be crushed small enough to pass a four-inch ring and remain on a two-inch ring; (2) the stone must be free from dust.

Fluxing stones used in the production of steel.—Limestones are used in the manufacture of steel in the basic open-hearth process. By the use of limestone, the fluxing of the silica and the alumina takes place, the manganese, carbon, and practically all of the phosphorus and a large portion of the sulphur is removed.

In a letter to the writer, Mr. C. H. Elliott, Superintendent of the Open-Hearth and Bloomington Mill Department, Atlanta Steel Company, says:

> For limestone, the specification is simple: as low in silica as possible, also iron and aluminum oxide and magnesium carbonate, and as high in calcium carbonate as possible. In other words, as pure a calcium carbonate as one can conveniently and economically secure.
>
> Dolomite is used to repair the scorification of the hearth due to the action of the slag. As the dolomite is also received into the slag as it is worn away and dissolved by the slag and becomes a part of it, it adds to the basicity of the slag, but its assistance is not very great. The specification for dolomite is the same as that for limestone. One would like as near a theoretical dolomite as possible.
>
> In the limestones we try to avoid and reject all samples running under 92 per cent. calcium carbonate, as the presence of more than 3 per cent. SiO_2 or 4 per cent. $MgCO_3$ makes the stone undesirable. The silica is undesir-

[1]Hoffman, iron and steel.

able because it lowers the efficiency of the flux for removing the silicon and phosphorus from the molten metal and the magnesia, because it makes the slag too refractory and therefore requiring too much heat to reduce it to a fluid state.

Southern pig iron is high in phosphorus, ranging from .50 to 1.40 per cent., and to remove this relatively large amount of phosphorus requires a slag of 20 per cent. silica or less. If the silica exists in the slag to a greater extent than 20 per cent., the removal of the phosphorus is very uncertain.

The following analyses show the chemical character of the dolomites and limestones used in the asic open-hearth process by the Atlanta Steel Company[1].

Analyses of Dolomites and Limestones Used by the Atlanta Steel Co.

Dolomites and Limestones	SiO_2	Al_2O_3 and Fe_2O_3	$CaCO_3$	$MgCO_3$
Dolomite from—				
Shook & Fletcher, Birmingham, Ala	.96	.57	52.82	45.51
Birmingham Realty Co., Birmingham, Ala	.82	1.06	53.71	44.91
Birmingham Realty Co., Birmingham, Ala	2.72	1.74	51.19	45.61
Ladd Lime & Stone Co., Cartersville, Ga	.68	1.62	52.97	44.99
Limestone from—				
Chickamauga Quarrying & Construction Company, Chattanooga, Tenn	2.18	.72	95.24	1.86
American Chemical Manufacturing Co	1.32	.34	95.13	-----

Copper smelting.—A great deal has been written about the composition of copper slags; however, very little information is available regarding the bases, that is, ferrous oxide, manganous oxide, lime, magnesia, barite, alumina, zinc oxide, etc., which are among the principal slag forming substances dealt with in copper smelting. Of the above, only the calcareous materials, lime and magnesia, will be discussed.

Limestone and dolomite are both used in copper smelters to add sufficient basic flux so that the acid silica content of the slag will not reach a maximum of more than 40 per cent. While it is entirely practicable to make slags which contain more than 40 per cent. of silica, it is not the general practice. The formation temperature and

[1]Analyses furnished by Mr. C. H. Elliott, Atlanta Steel Co.

the flowing temperature of a slag depends to a large extent upon the chemical composition of the base present. Very pure high-calcium limestones are used in nearly all copper smelters; however, a dolomite was used with considerable success at the Golden Reward plant, Deadwood, North Dakota, by Franklin P. Carpenter[1]. The materials used consisted of siliceous gold ores containing only a trace of sulphur, pyrite and pyrrhotite; later, this was replaced by siliceous pyritic concentrates from Homestake. The principal basic flux was a dolomitic limestone. The dolomitic limestone was preferred to pure limestone and Mr. Carpenter[2] says:

> Nothing like a scientific attempt has ever been made to determine the formation-point of our slags, hence I can not say that they were less fusible than they would have been with all lime and no magnesia. They did seem more liquid, and certainly less magnesian limestone was required for the same work. This was due, of course, to the lower combined weight of magnesia.

Peters[3] says, in regard to the replacement of lime by magnesia:

> All experiments with which I am acquainted indicate that the replacement of lime by magnesia causes a moderate rise in the formation temperature until about three-fourths of the lime has been replaced, beyond which limit the temperature rises with great rapidity.

Some interesting observations were made by Hoffman,[4] which are referred to under the discussion of the use of limestone in the metallurgy of lead.

Fulton and Knitzen[5] are of the opinion that "some magnesia up to 8 or 10 per cent. replacing lime is desirable, owing to its greater silica saturating power and the lesser specific gravity of the resultant slag."

The physical and mechanical conditions of ore in the blast furnace is of very considerable importance in the smelting process. The many difficulties which may result from the "fines" can be largely overcome by some method of consolidation of "fines" into lumps. No material

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[1] Carpenter, Franklin P., Pyritic Smelting in the Black Hills: Trans. Amer. inst. Min. Eng., Vol. XXX, 1906, pp. 764-777.

[2] Ibid, p. 773.

[3] Peters, E. D., Footnote, Mineral Industry, 1909, p. 246.

[4] Trans. Amer. Inst. Min. Eng., Vol. XXIX, 1900, p. 642.

[5] Fulton, Chas. H., and Knitzen, Theodore A., Sulphide Smelting at the National Smelter of the Horse Shoe Mining Co., Rapid City, S. Dak.: Trans. Amer. Inst. Min. Eng., Vol. XXXV, 1905, p. 329.

has been more frequently used for this purpose than freshly burned lime. The lime is slaked with considerable water and the resulting milk of lime thoroughly incorporated with the ore until the entire mass is like a thick mortar. The amount of lime necessary for the consolidation of the "fines" varies according to the physical condition of the ore, the amount of sulphates present, etc.; however, it is usually from 5 to 12 per cent. Sometimes it is fed into the furance in the form of partially dried mud or made into balls and heated thoroughly dry and hard. The addition of lime is in almost all cases favorable to subsequent fusion. On account of the ease of consolidation, its general availability, fluxing qualities, and cheapness, it is regarded as the most useful substance known for the consolidation of "fines."

Lead smelting.—The value of lime in the smelting of galena (PbS) was not recognized until 1907. Previous to this time, limestone or dolomite was added in the smelting of lead only in the reverberatory process for the mechanical effect of stiffening the charge; however, it was observed that when the limestone was added the charge became glowing, so that it was known that its addition had a chemical as well as a physical effect.

In 1897, Huntington and Haberlein pattented a process of oxidizing galena by forcing air under pressure through a mixture of galena and lime or limestone and it became established as a successful and economic process in 1905.

At the present time, three methods of oxidizing galena by the addition of limestone or gypsum are carried out on a commercial scale, and are known as lime roasting or "pot roasting": (1) the Huntington-Haberlein process[1]; (2) The Carmichael-Bradford process[2]; and (3) the Solvesberg process[3].

The chemical effect of the addition of the lime in the various processes has been discussed by many workers and the more important papers have been published in book form by Ingalls.

Glass manufacture.—Limestone has an important use in the manu-

[1]Eng. & Min. Jour., Vol. LXXX, 1905, p. 106.

[2]Ingalls, Eng. & Min. Jour., Vol. LXXXI, 1906, p. 9.

[3]Min. Mag., Vol. XII, 1905, p. 391.

facture of glass. Both high-calcium and dolomitic limestones are used and it depends on the character of the finished product as to just what the specifications of the chemical composition of the stone shall be. The function of lime and magnesia is to act as a flux and to combine with the silica to form a silicate. Burchard[1] says, "magnesia, which is more apt to be introduced into glass materials through limestone than through sand, is troublesome because it renders the batch less fusible." While magnesia may be objectionable in the manufacture of certain kinds of glass, considerable quantities of calcined dolomite are used in the manufacture of flint and plate glass.

Glass may be divided into four general classes, namely, plate, window, green bottle, and flint. When limestone is used in the form of carbonate, it is ground fine enough to pass a twenty-mesh sieve or finer. After first crushing the limestone, it is usually ground by rock-emory mills or by a mill of the impact pulverizer type.

Chemical Uses

Sodium carbonate.—The Le Blanc[2] process of manufacturing sodium carbonate is as follows: After sodium sulphate (Na_2SO_4) has been formed by the action of sulphuric acid (H_2SO_4) with sodium chloride (NaC1) at a high temperature, limestone and coal or charcoal is added and calcined in a reducing flame. Sodium sulphate ($NaSO_4$) + carbon (2C) + limestone ($CaCO_3$) = sodium carbonate (Na_2CO_3) + lime sulphide (CaS) + carbon dioxide ($2CO_2$).

The carbon dioxide passes off into the air and the sodium carbonate is separated from the sulphide of lime by leaching with water at a moderate temperature for the sulphide of lime is practically insoluble in water.

The Solvay process with calcium chloride as a by-product is as follows: Carbon dioxide is passed into a solution of sodium chloride saturated with ammonia. Under certain conditions the reaction is as follows: Salt (NaC1) + ammonia (NH_3) + water (H_2O) + carbon dioxide (CO_2) = sodium bi-carbonate ($NaHCO_3$) + ammonium chlo-

[1]Burchard, E. F.; Bull. U. S. Geol. Survey, No. 285, pp. 453-454.
[2]Encyc. Britan., Vol. XXII, p. 242.

ride (NH_4Cl). The sodium bi-carbonate being less soluble than the accompanying compounds is separated by filtering. The solution containing ammonium chloride is treated with calcined limestone. The ammonium gas is liberated and used again in the process, while calcium chloride and sodium chloride are both contained in the waste liquor and the calcium chloride is obtained by crystallization.

Calcium chloride.—The three important methods of manufacture of calcium chloride (chloride of lime, muriate of lime, bleaching powder) are: (1) as a by-product in the manufacture of sodium carbonate by the solvay process. (In this process more than sufficient is made to supply the demand): (2) slaked lime is placed in leaden vats and treated with chlorine gas; (3) dissolving limestone in dilute hydrochloric acid. Calcium chloride crystalizes out when the solution is concentrated by evaporation.

Calcium chloride is used largely as a disinfectant. When it is heated to redness on platinum it looses practically all of its water and is used as a dehydrating agent.

Calcium carbide.—This is prepared in the electric furnace by fusing lime oxide and carbon in the form of coke or charcoal. It is used in the manufacture of acetylene gas and cyan amid.

Cyan amid, or "lime nitrogen," is manufactured by passing nitrogen gas, which is obtained from liquid air, over calcium carbide. It is an important fertilizer.

Calcium nitrate.—Ground limestone is an important constituent in the manufacture of calcium nitrate, which is used so extensively as a fertilizer. Calcium carbonate or lime is treated with nitric acid. Ground limestone is also used as a fertilizer filler.

Dyed textiles.—Ground limestone is used to neutralize the acid condition of dyed textiles.

Carbonic acid gas.—The simplest method of obtaining carbonic acid gas consists in the calcination of magnesite, which is almost pure magnesium carbonate ($MgCO_3$). When magnesite is not available, dolomites are often used. The calcination of calcium carbonate ($CaCO_3$) will furnish a considerable quantity of carbonic acid gas; however, the heat required to calcine the calcium carbonate is much higher than that required of magnesium carbonate.

The dolomitic marbles of Pickens County, Georgia, are used by the Pratt Laboratory of Atlanta in the production of a commercial carbonic acid gas, in the manufacture of epsom salts and gypsum.

Other chemical uses.—Lime is also used in the manufacture of caustic soda, acetic acid, in the purification of gas and water, in the manufacture of Bordeaux mixture, etc.

Crushed Limestone

Road Metal.—Limestone for use as road metal should be thoroughly compact and consolidated. The semi-crystalline and highly siliceous limestones possess the greatest resistance to wear. Limestones possess high cementing qualities and the fines and screenings, when used as a top dressing, fill the empty spaces and give the essential qualities of a good road surface, namely, hardness and smoothness. It is important to know the cementing qualities of the dust produced by any road metal. The consolidated crypto-crystalline and crystalline limestones of North Georgia, and the cherts associated with some of these limestones, are the most important materials used for road metal in that part of the State. They all possess good wearing and cementing qualities.

Ballast.—In the past, limestones of most any character have been used for ballast without any serious consideration regarding the properties considered today as essential. Limestones are extensively used for ballast on account of the ease with which they can be tamped under the sleepers, their cementing properties, and the cheapness with which they can be quarried and crushed when compared with other stone suitable for this purpose. The stone should be crushed so that it will pass a two and one-half inch and lodge on a three-quarter inch ring. The stone can be packed very tightly under the sleepers, and should be dressed with "fines" or screenings to occupy the large number of spaces between the stone. Most any variety of calcareous stone may be used for dressing, the purpose of which is to form a more compact mass attained through the filling of the empty spaces. The siliceous and semi-crystalline limestone as well as the holo-crystalline marbles of Georgia possess a high crushing strength making them eminently suitable for use as ballast.

Concrete.—Limestone crushed for use in concrete should be free from excessive amounts of dust and should vary somewhat in size and shape to assist in close packing. It should all pass a one-quarter inch ring. The crushed stone is mixed with cement and sand and the value of the stone depends on its strength, durability, size, shape, etc. The limestones and dolomites of North Georgia, with the exception of those of extremely argillaceous character, can be used for concrete construction.

Flooring.—Limestones and dolomites which possess a fine crystalline texture and take a good polish are crushed and mixed with white Portland cement for flooring.

The Cambrian fine crystalline white dolomitic marble of Fannin, Gilmer, Pickens, and Cherokee counties are entirely suitable for this use. At the present time they are only being developed in Pickens county. The preparation of the stone is as follows:

The rock is fed into a crusher and the crushed rock is passed over screens to separate the dust. It is then fed into a gyratory crusher where it is broken into many sizes. It is put on the market in sizes 1, 2, 3, etc., No. 1 passing through 1/4-inch; No. 2, over 3/8-inch; and No. 3, over 1/2-inch ring.

BUILDING STONES

The most important calcareous rocks quarried in Georgia and used for building purposes are the white and vari-colored crystalline Cambrian marbles of Pickens County[1]. Marbles also occur in Fannin, Gilmer, and Cherokee counties.

The Cambrian limestones of the Appalachian Valley are seldom used for building on account of the clayey impurities present and the usual large amount of secondary calcite developed in stringers throughout the limestone.

The Knox dolomite of Cambro-Ordovician age has not been used

[1]McCallie, S. W., The Marbles of Georgia: Bull. Geol. Survey of Ga. No. 1, 1907.

except for local purposes. The high cost of quarrying this heavy bedded and massive limestone will probably prevent its use as a building stone.

The Chickamauga limestones of Ordovician age are the only limestones of the Appalachian Valley region of Georgia that have been widely used for building. At Chickamauga, Walker County, the limestones of the Chickamauga formation have been pretty extensively quarried for trimmings, door steps, foundations, curbing, construction of buildings, and by the United States Government in culvert construction on National roads in the vicinity of Chattanooga. All sizes of stone can be obtained in the same quarry, due to the variation in thickness of the bedding and the numerous joints developed perpendicular to stratification. The limestone splits parallel to the bedding and along these joint planes. The Silurian limestones (Rockwood formation) are always thin bedded and never available for building purposes.

The Floyd and Bangor formations of Mississippian (Lower Carboniferous) age contain the most important and promising building stone of northwest Georgia. The limestones of the Floyd formation seldom exceed 100 feet in thickness, while those of the Bangor formation sometimes reach a thickness of 800 or 900 feet. These limestones contain oölitic, crinoidal, and crystalline beds. The geologic conditions nearness to markets, railroad facilities, and general favorable conditions of quarrying are often such as to make these limestones of economic value.

Mortars and Plasters

Both high-calcium and dolomitic limes are used in preparing mortars and plasters. The fact that slaked lime mixed with sand hardens when exposed to the atmosphere, together with the ease of preparation, plasticity and adhesive properties, makes it valuable for use, both in interior and exterior construction. The sand prevents shrinkage and indirectly causes a greater strength by aiding the mass in the absorption of carbon dioxide by the lime, forming the carbonate.

Hydrated lime is now extensively used as a mixture with natural and Portland cement for use as mortar. When lime is added up to 30 per cent. it adds strength to the cement and makes it more impervious.

All limes used with sand for mortars and plasters should be thoroughly slaked. If the lime is not thoroughly slaked it will contain some quicklime and the absorption of moisture by the quicklime causes the mortar or plaster to expand and crack.

Agricultural Purposes

High-calcium and magnesium limes are preferable for agricultural purposes. High-calcium limes are used on soils containing considerable magnesia, while the magnesium limes are more suitable for soils free of this constituent. Argillaceous limes are only used when high-calcium and magnesium limes are not available, for the agriculturist desires the greatest percentage of calcareous materials possible in the stone to perform the chemical and physical functions in a soil already containing sufficient silica and alumina.

Chemical function of lime.—Phosphoric acid, potash, and lime are the principal constituents in the soil that need constant replacement. When lime is applied to the soil it unites with silica and alumina, which are the two most abundant soil constituents, and also with other soil substances. Lime makes potash available for plants, and it reacts with the inert compounds of iron and alumina, which may be combined with phosphoric acid and causes the phosphorus to become available for plant food. It also reacts with organic compounds and manures and liberates ammonia and neutralizes organic acids which result from organic decomposition.

Physical effect.—The physical effect of lime on the soil which is largely due to chemical reactions that have taken place between lime and certain soil constituents, is often of as much value to the plant as the indirect effect of fertilization due to the liberation of plant food. The physical characteristics of soil such as texture, porosity, character of soil particles, which increases or decreases the capillarity, etc., are of considerable importance in determining the value of soils for agricultural purposes.

Lime reduces the plasticity of clayey soils and makes the clay more porous and through a greater porosity it promotes nitrification. Lime furthermore on sandy soils, by chemical combination, forms silicates and performs the function of a cementing material, bringing the soil particles closer together, thus diminishing the porosity of the sandy soil.

It is especially desired to emphasize the fact that residual soils derived from limestone are usually as much in need of lime as those derived from sandstones, shales, or crystalline rocks. This can best be brought to the attention of the agriculturist by the analyses of a calcareous rock and a soil derived from it, copies of which are here given:

Analyses of Knox Dolomite[1] *and Soils in the Vicinity of Cave Springs, Georgia.*

Constituents determined.	Knox dolomite.	Soils.
Calcium carbonate ($CaCO_3$)	52.05	.01 to 2.00
Magnesium carbonate ($MgCO_3$)	36.32	
Alumina (Al_2O_3)	2.68	6.00 to 16.00
Iron oxide (Fe_2O_3)	2.10	
Silica (SiO_2)	6.47	60.00 to 80.00

In the process of rock disintegration, the calcareous matter is dissolved out of the rocks and is carried away in solution, thus forming soils by the accumulation of silica and alumina with a small percentage of other constituents. It is necessary to apply lime so that it will be uniformly distributed in the soil, in order to perform the physical and chemical functions above mentioned.

Amount of lime to be used.—The number of bushels of lime to be used per acre and the frequency of application depend on the character of the soil. A number of interesting results were brought out at the Maryland Agricultural Experiment Station and presented in their Bulletin No. 110, p. 9. The results of their experimental work shows

[1]Spencer, J. W., Paleozoic Group of Georgia: Geol. Survey of Ga., 1893.

that, all things taken into consideration, annual application of twenty bushels of lime to the acre is proportionally more effective than 50 to 60 bushels.

Lithographic Stone

Lithographic stone is a fine grained, homogeneous limestone of uniform chemical composition. It may vary in color, which is not such an important factor as constant physical character. The lithographic stones in practical use contain a low percentage of magnesia. The effect of acid on calcium and magnesium is so different that if the stone contains any considerable amount of magnesia it can not be evenly etched.

The following chemical analyses show the variation in chemical character of some lithographic stones[1]:

Analyses of Lithographic Stones.

Constituents determined.	Brandenburg, Ky.	Solenhofen Bavaria.	Mitchell Co., Iowa.
Insoluble in hydrochloric acid—			
Silica (SiO_2)	3.15	1.15	.78
Alumina and iron oxide ($Al_2O_3+Fe_2O_3$)	.45	.22	tr.
Lime (CaO)	.09	tr.	-----
Magnesia (MgO)	-----	-----	-----
Soluble in hydrochloric acid—			
Alumina (Al_2O_3)	.13	.23	.12
Ferrous oxide (FeO)	.31	.26	-----
Magnesia (Mgo)	6.75	.56	.07
Lime (CaO)	44.76	53.80	54.91
Soda (Na_2O)	.13	.07	.18
Potash (K_2O)			
Humus	-----	-----	.11
Hygroscopic water (H_2O)	.41	.23	-----
Water of composition (H_2O)	.47	.69	.35
Carbon anhydride (CO_2)	43.06	42.69	43.16
Sulphuric anhydride (SO_3)	-----	-----	tr.
Total	99.71	99.90	99.68

Mechanical admixtures of silica and alumina are objectionable, as

[1]Hoen, A. B., Iowa Geological Survey, Vol. XIII, 1902, p. 846.

they leave a roughened surface when the limestone is etched. Calcite in veins or distributed irregularly throughout the stone is also objectionable. A cross section perpendicular to the plane of stratification shows the character of the texture. The hardness required to suit the engraver is best determined by the engraver himself. Absorption and specific gravity tests are important.

Lithographic stone is not confined to any geologic formation, but may be found in any sedimentary rocks where the conditions of sedimentation were satisfied.

Paper Manufacture

Paper is largely manufactured from two types of material: (1) straw, rags, etc.; or (2) wood pulp. In the manufacture of paper from straw and rags, lime oxide is used to dissolve any fatty impurities which may be present. The lime oxide should be derived from a high-calcium limestone.

In the manufacture of paper from wood pulp, there are two important methods of reducing the wood to pulp: (1) the soda process; and (2) the sulphite process. High-calcium lime is used in the former process while dolomitic lime is used in the latter.

Leather Manufacture

High-calcium lime, low in silica, alumina and iron, is preferable in the tanning process of hides and skins. Lime in solution as "milk of lime" is used to remove the flesh adhering to the skins, to loosen the hair, and to soften and swell the hides for the further processes to which they are subjected.

Sugar Manufacture

Calcium oxide in solution in the form of "milk of lime," used in the manufacture of sugar, must be derived from a high-calcium limestone, low in silica, alumina, and iron, and especially low in magnesia. Magnesia forms a soluble compound with sugar, while calcium forms an insoluble tricalcium sucrate which may be separated by filtering and later when carbon dioxide gas is passed into solution it is broken down into calcium carbonate and a solution of sugar.

Manufacture of Glue

In the manufacture of glue, organic animal refuse is treated with unslaked or lime hydrate in the form of "milk of lime" to remove the oils, flesh, and blood, and to disintegrate the tissues and to soften the marrow.

Soap and Candles

High-calcium limes with a small quantity of magnesia are used with sodium carbonate to reduce it to caustic soda which is used with fats to form soap. By the addition of sulphuric acid the free organic acids are separated and are used in the manufacture of candles.

Ground Limestone

Agricultural purposes.—Ground limestone is used to perform the same functions in soils as burnt lime. The chemical activity of the ground limestone will depend on the degree of fineness of the particles. For agricultural purposes they are usually ground to a fineness of 60 to 70 mesh. Ground limestone can be applied at any season of the year. It can be equally distributed on or into the soil and the "burning," which may result from the excess of slaked lime due to the crude method of distributing it upon the surface, is not likely to occur.

Lime is also used largely for many purposes which have not been mentioned above. Among the more important uses are: the manufacture of sand-lime brick, slag cement, pottery, hydrating agents, disinfecting compounds, etc.

BURNING OF LIMESTONES

The high-calcium, magnesium and dolomitic limes are all produced in the same general way, namely, by the decarbonation of limestone. The character of the resultant product depends largely on the chemical composition of the calcined rock. High-argillaceous limestones are seldom used for lime, but more especially in the manufacture of the complex cements. The chemical reactions which take place in the burning of each variety will be discussed under the classification of limes. In the manufacture of quicklime, the carbon dioxide must be driven from the limestone, the water in the limestone must be evaporated and the stone must be heated to its dissociation temperature.

The dissociation temperature varies for each variety of limestone and also in two limestones of the same chemical composition, due to differences in texture, hardness, compactness, etc. Water is often added in the burning process forming when heated steam, which, in association with the carbon dioxide given off by the limestone, still further aids in the dissociation of the stone.

The types of kilns most used today in burning limestone are the intermittent and the continuous kilns which are here described.

Intermittent Kilns

Intermittent kilns are vertical with mixed feed. After the kiln is charged, burned, and cooled, the lime is drawn. While this method of manufacture is still in use in the rural districts in some localities, it is regarded today as distinctly primitive.

Continuous Kilns

In all of the continuous kilns, the burnt lime is withdrawn from below while the limestone is added at the top and there is no interruption in the production, unless so desired by the operator. These kilns are of four types: (1) vertical kilns with mixed feed; (2) vertical kilns with separate feed; (3) ring or chamber kilns; (4) rotary kilns.

Vertical kilns with mixed feed.—These are of many types, and on account of their ease of construction they are usually made in the vicinity in which the lime is manufactured. They vary from square or bottle-shaped stone kilns to those made of iron or steel plates and lined in the interior with fire-brick. The feeding of the kiln takes place from the top where first a layer of coal and then a layer of limestone is added and so on alternately and continuously, or at regular intervals. A fire is started at the bottom and as it works its way up, the limestone is calcined and is drawn at the bottom. The manufacture of lime by this process has the following advantages: (1) construction is cheaper than separate feed kilns or chamber or ring kilns; (2) less amount of fuel is necessary to burn the lime; (3) the yield is larger for the same size of kiln. The lime is usually of lower grade however than that which is burnt in separate feed kilns, due to admixture of ash and clinker with lime.

Vertical kilns with separate feed.—In these kilns the hot fuel gasses, only, come in contact with the limestone, which is fed in at the top while the fuel which consists of coal or wood, is fed into fire boxes which are usually set into the walls of stone kilns, while in the more modern iron and steel kilns, the fuel is burnt in horizontal furnaces from two to four in number built out from the kiln above the drawing pan. Producer gas is also used.

Ring or chamber kilns.—The Hoffman kiln[1] is the best known type of the ring or chamber kiln, and while it has been used extensively in Germany for the manufacture of lime as well as Portland cement and brick, it has not come into use in this country. The fuel consumption is low in comparison with the vertical kiln; however, it requires skilled labor for each operation.

Rotary kilns.—The New York lime company at Natural Bridge, N. Y., was the first company in this country to carry on the successful manufacture of lime in the rotary kiln. This method of manufacture results in a lime which is superior in many ways to lime burned in the vertical kiln and many difficulties of burning are done away with. The following references are cited for those interested in the manufacture of lime in the rotary kiln:

Rock Products, Vol. IV, No. 1, p. 35.
Frasch, Mineral Industry, Vol. VII, p. 491.
Spackman, Henry O., Rock Products, Vol. IV, No. 2, p. 38.
Rock Products, Vol. IV, No. 5, p. 45.

Fuel Used in Lime Burning

The two principal materials used in Georgia for lime burning are wood and coal. Wood is best suited technically. With good wood, more lime, as a rule, can be produced than with coal; however, the cost of wood today is usually slightly greater per ton of lime produced.

Coal is gradually replacing wood for the burning of limestone, due to the scarcity and high cost of wood in most localities. With the modern appliances for burning coal the many objections to its use which formerly existed are done away with.

The cost of burning depends on: (1) the chemical character of

[1]Frasch, Mineral Industry, Vol. VII, p. 491.

the limestone, whether high-calcium, dolomitic, or argillaceous; (2) the physical character of the rock, nature of crystallinity, texture, degree of consolidation, etc.; (3) the kind of fuel used, quality, and cost; (4) the skill of the burners.

Few lime burners keep any accurate account of the amount of fuel consumed per ton of lime. Statistics are not available on the cost of production of lime in this State; however, for those interested in the character of fuels used in other states and the cost of production, the following references are cited:

1905—Grimsley, G. P., Clays, Limestones, Cements: W. Va. Geol. Survey, Vol. III, 1905, pp. 360-368 and 383-384.

1906—Orton, Edward, and Pepple, Samuel Vernon, Limestones, Lime and Sand-lime Brick: Geol. Survey of Ohio, 4th ser. Bulls. 4 and 5, 1906, pp. 291-293.

1907—Eckel, Edwin C., Cements, Limes and Plasters: 1907, pp. 98-112.

1907—Buehler, H. A., The Lime and Cement Resources of Missouri: Mo. Bureau of Geology & Mines, Vol. VI, 2nd ser., 1907, pp. 37-43.

CLASSIFICATION OF COMMON LIMES

The common limes are classified, according to their chemical composition, as follows: high-calcium limes, magnesian limes, dolomitic limes, dolomites, and argillaceous limes.

HIGH-CALCIUM LIMES

When limestones contain less than 5 per cent. of magnesium carbonate and a small percentage of other impurities they produce, when decarbonated, a high-calcium lime. The chemical changes which take place in a theoretically pure limestone in the burning process are the following:

Limestone ($CaCO_3$) + heat = quicklime (CaO) + carbon dioxide (CO_2).

If the quicklime is exposed to the atmosphere it will absorb water and form hydrated calcium oxide ($Ca(OH)_2$). The same result can be had by the addition of water: $CaO + H_2O = Ca(OH)_2$. After the lime has "slaked" and is further exposed to the atmosphere it takes up carbon dioxide (CO_2) and the chemical reaction may be expressed as follows:

Calcium hydrate ($Ca(OH)_2$) + carbon dioxide (CO_2) = calcium carbonate ($CaCO_3$) + water (H_2O), thus the calcium oxide by combination with the carbon dioxide of the air returns to the carbonate and the water evaporates into the air. High-calcium limes are known to the mixer as "strong limes," on account of the fact that they will carry more sand than other limes. A theoretically pure limestone carries 56 parts by weight of calcium oxide (CaO) and 44 parts by weight of carbon dioxide (CO_2), and if we assume that decarbonation is complete we may express the result as follows:

100 pounds calcium carbonate ($CaCO_3$) + heat = 56 pounds of quicklime (CaO) + 44 pounds of carbon dioxide (CO_2).

MAGNESIAN LIMES

When a limestone contains more than 5 per cent. and less than 30 per cent. of magnesium carbonate it produces, when burnt, a magnesian lime. The carbon dioxide is driven off precisely as in a theoretically pure high-calcium lime; however, there are some differences in burning and usually less heat is required for decarbonation.

DOLOMITIC LIMES AND DOLOMITES

Most of the commercial limes carrying magnesia approach the composition of a dolomite. When a dolomite is calcined, the amount of calcium and magnesium oxides in 100 pounds of dolomite can be determined and expressed in a commercial formula as follows:

Calcium carbonate ($CaCO_3$) 54.3 per cent. + Magnesium carbonate ($MgCO_3$) 45.7 per cent. = a theoretical dolomite.

Calcium carbonate is made up of 56 per cent. calcium oxide (CaO) and 44 per cent. carbon dioxide (CO_2). If we now assume that decarbonation is complete, the loss of carbon dioxide on calcination, due to the calcium carbonate, will be $54.3 \times 44 = 23.9$ per cent. carbon dioxide (CO_2), and the residue of calcium oxide due to the calcium carbonate will be 30.4 per cent.

Magnesium carbonate contains 48.0 per cent. magnesium oxide (MgO) and 52. per cent. carbon dioxide (CO_2), hence $45.7 \times .52 =$ 23.7 carbon dioxide (CO_2) and the residue of Magnesium oxide (MgO), due to the magnesium carbonate, will be 22 per cent. The total composition of the original rock may be expressed as follows:

The original rock contains in 100 lbs.	30.4 lbs.	CaO
and	22.0 "	MgO
making a total of	52.4 "	CaO and

MgO contained in 100 lbs. of dolomite.

ARGILLACEOUS LIMES

Limestones high in silica and alumina are seldom burned for common lime, but are extensively used in the manufacture of complex hydraulic cements.

HYDRATED LIMES

When quicklime is exposed to the atmosphere for any length of time or if water is added the lime combines with the water to form slaked or hydrated lime. The chemical reaction is as follows:

Lime (CaO) + water (H_2O) = lime hydrate ($Ca(OH_2)$.

It has been realized for many years that when quicklime (CaO) is slaked by the ordinary laborer, too much or too little water is added and an unsatisfactory product is likely to result. The quicklime generates heat on slaking, and if too little water is added "burning" is likely to occur, while too much water is equally as objectionable. It is almost impossible for the day laborer to mix the quicklime and water in the proper proportions. The results of a poorly mixed lime hydrate may cause "pitting" and cracking of the mortar. Lime hydrate can now be carefully manufactured and the unsatisfactory results mentioned above done away with.

METHOD OF MANUFACTURE

(1) The carbon dioxide must be driven from the limestone as in any ordinary process in the manufacture of quicklime (CaO). (2) The quicklime must be ground to a fairly uniform small size. In some plants it is crushed to about one inch while in others it is reduced to one-half inch size or to a fine powder. (3) The ground quicklime must be intimately mixed with sufficient water. There are a number of methods used for hydrating the quicklime; however, the principal object of them all is to thoroughly and intimately mix the quicklime

and water. The amount of the water to be added depends on the chemical character of the quicklime. Different amounts are added to a high-calcium, a dolomitic or a high-magnesium lime, and the amount to be added in each case is determined by experience. (4) Any unhydrated lumps or cores must be separated by screening from the fine slaked lime.

The very fine hydrated lime is packed in bags and sold according to the standards adopted by the hydrated lime manufacturers of the United States[1]. The cost and equipment of a hydrated lime plant depends on the character of the stone and the method of manufacture.

ADVANTAGES OF HYDRATED LIME

Hydrated lime is characterized by the following advantages: (1) It will not air slake, for it has taken up already the necessary amount of water of combination. It will therefore keep for a long time in barrels, sacks, or paper bags. As it does not absorb water, there is no danger of expansion which takes place in quicklime (CaO), due to the absorption of water from the atmosphere. It can be shipped by water and there is no danger of heat being generated and consequent fire. (2) It does not contain grit or "core"—this is separated by screening. (3) "Popping" and cracking of mortars made with hydrated lime are not so likely to occur as from lime-hydrate roughly prepared. (4) It can be mixed uniformly with cement and is used for the purpose of water-proofing the latter or to make a more easily troweled mortar.

USES OF HYDRATED LIME

The more important uses of hydrated lime are: for purifying water, washing boilers, iron moulding, agricultural purposes, cold water paints, glass industry, a dry spray and in solution with sulphur for fruit trees, etc. Hydrated lime mixed with natural cements and gypsum makes a slow setting, but very hard, plaster. Hydrated lime added to and ground with natural cement rock adds greatly to the strength of the cement mortar[2]. By the addition of hydrated lime to Portland cement

[1]Engineering News, Sept. 8, 1904, Vol. 52, p. 220.

[2]Bleininger, A. V., The Manufacture of Hydraulic Cements: Geological Survey of Ohio, Bull. 3, 4th ser., 1904, p. 191.

mortars, better working properties, a greater density, and waterproofing qualities are the result. Hydrated lime as a disinfectant is equally as good as the quicklime. It can be put up in small packages for sale and can be kept almost indefinitely. Hydrated lime is used for many other purposes.

LITERATURE ON HYDRATED LIME

1903—Brigham, S. Y., The Manufacture and Properties of Hydrate of Lime; Engineering News, Vol. 50, Aug. 27, 1903, pp. 177-179.

1903—Warner, C., Hydrated Lime: Engineering News, Vol. 50, Oct. 8, 1903, pp. 320-321.

1903—Warner, C., Strength Tests of Mixtures of Hydrated Lime and Portland Cement: Engineering News, Vol. 50, Dec. 17, 1903, p. 544.

1904—Peppel, S. V., Lime Experiments: Rock Products, Vol. 3, April-May, 1904, p. 17.

1904—Brigham, S. Y., Hydrated Lime: Engineering News, Vol. 50, June 9, 1904, p. 543.

1904—Warner, C., Standards Adopted by Manufacturers of Hydrated Lime: Engineering News, Vol. 52, Sept. 8, 1904, p. 220.

1906—Orton, Edward, Jr., and Peppel, Samuel Vernon, The Limestone Resources and the Lime Industry of Ohio: Bull. Geol. Survey of Ohio No. 4, 4th ser., July, 1906.

1910—Lazell, E. W., Comparative Tests of Lime Mortar, Both Tension and Compression—Hydrated Lime and Sand—Cement Lime and Sand: Rock Products, Vol. X, No. 3, Sept. 22, 1910, pp. 48-51.

1910—Matthews, E. B., and Grasty, J. S., The Limestones of Maryland: Maryland Geol. Survey, Vol. VIII, pt. 3, 1910, pp. 225-229.

CLAYS, SHALES AND SLATES

CLAYS

Origin

Clays consist of a heterogeneous mixture of rock constituents the nature of which depends upon the character of the material from which the clay is derived. Clays are all of secondary origin and are derived from either igneous, metamorphic, or sedimentary rocks, resulting from the disintegration of these rocks by the normal processes of weathering and erosion. Clays may be either residual or transported. Residual clays are those derived *in situ* from the underlying rocks. Transported clays consist of stream, glacial, lacustrian, marine, and estuarine deposits.

Physical Character

The residual clays, resulting from the decomposition of igneous, metamorphic and sedimentary rocks, are seldom uniform in their physical character and usually contain fragments of siliceous nodules, concretions, etc., which may be interspersed throughout the original rocks. The transported clays which consist of stream deposits vary from fine to coarse-grained clays, but are seldom uniform over a sufficient thickness for economic use in the manufacture of cement.

Chemical Character

The residual and transported stream clays of North Georgia and the consolidated shales and slates may all be of similar chemical character. However, some chemical constituent usually predominates and they may be classified as siliceous, aluminous, ferruginous, and carbonaceous.

SHALES AND SLATES

Origin

Shales consist of fine muds or clays which have been at some time deposited in water and have been subsequently subjected to pressure and consolidated into rocks, possessing characteristic cleavage or other structures. The pressure was due either to the weight of the overlying rock formed by subsequent deposition, to forces to which these rocks were subjected during mountain forming periods of the earth's crust, or to both of these causes combined. Under further pressure and increased temperature the character and structure of the shale were altered, chemical changes took place, the rock underwent a recrystallization, perfect cleavage and fissility developed and the shales were changed into slates.

Physical Character

Shales vary in color from cream and white to black, depending on the presence or absence of carbonaceous matter and variations in chemical composition.

In texture, the shales vary from fine-grained, close, compact, consolidated clays to semi-crystalline and crystalline slates. Shales are characterized by their fissile nature which is usually parallel to the original bedding while the cleavage of a slate may be at any angle to the stratification. The weathering of shales is often a criterion of their chemical composition. Shales weather splintery, hackly, pisolitic-like, etc. Argillaceous shales usually break down at once, on exposure, to clays, while the more siliceous varieties weather hackly or splintery, and when they are highly crystalline, as in commercial slates, they retain their fissile character when exposed to the weather for a long period of time.

Slates are quite deficient in plasticity, while shales are usually somewhat deficient; however, shales which have been superficially disintegrated by weathering agencies often contain sufficient plasticity for the manufacture of brick of superior quality.

Chemical Character

The chemical composition of shales varies between rather wide limits. Silica and alumina are the most abundant constituents present, while lime, magnesia, manganese, iron, titanium, and the alkalies are present in smaller amounts. The term shale signifies no specific chemical composition; however, as a geologic term it signifies fineness and uniformity of composition over a unit of uniform lithologic similarity.

Classification of Shales

Shales may be described as siliceous, aluminous, ferruginous, calcareous, and carbonaceous.

Siliceous shales.—Distinctly siliceous shales of extremely fine grain are rare. They represent the transition stage between the formation of normal shales and sandstones.

Aluminous shales.—Shales with a relatively high content of alumina in comparison to silica are referred to as aluminous shales.

Ferruginous shales.—Unweathered shales usually contain iron in the form of ferrous carbonate which gives to the shale a dark gray to bluish gray color; the carbonate becomes oxidized in the weathered shale to the ferric oxide, which gives the shale a reddish or brownish appearance. Iron may occur as ferrous carbonate in the form of concretions. When the concretions occur in large quantity or in such a state that they can not be economically separated the shale becomes worthless for most commercial purposes. Iron is liable to occur in the form of iron sulphide (iron pyrite) and it is equally as objectionable as the concretions above mentioned. The iron sulphide is oxidized in the weathered shale to the sulphate and gives a somewhat mottled yellow color to the shales.

Calcareous shales.—Shales carrying more than 5 per cent. of lime are usually referred to as calcareous. Shales which rest conformably upon limestone and thin bedded shales interstratified with limestones are usually calcareous. A shale may owe its content of lime both to organic and inorganic agencies.

Carbonaceous shales.—These shales are characterized by the presence of carbonaceous matter which may vary from a trace to at least 14 per cent. The shale is dark brown to black in color and where the content of iron is high the color is often green.

HYDRAULIC LIMES, NATURAL AND PORTLAND CEMENTS

THE RELATION OF HYDRAULIC LIMES, NATURAL AND PORTLAND CEMENTS

Hydraulic limes, natural cement and Portland cement differ from one another in physical and chemical character. Their peculiar characteristics are due as much to their physical condition, resulting from a definite process of manufacture, as to their chemical composition. Matthews and Grasty[1] comment as follows on the classification of these compounds:

Nearly all formulas have supposed that cements and hydraulic limes owe their hydraulic properties to definite chemical compounds. The most recent investigations which have been made upon this class of materials tend to prove that they are not definite compounds, but what are known to physical chemists as solid solutions, and are similar in character to blast furnace slags, steel and alloys. It would seem better, therefore, to classify these compounds according to their physical properties and method of manufacture, rather than according to their chemical characteristics. Such a classification would be the following:

1. Common lime: Limes made by burning relatively pure limestones, which, when mixed with water, slake and show no hydrulic properties.
2. Hydraulic limes: Limes made by burning impure limestones at a low temperature which slake with water, but which show hydraulic properties.
3. Natural cements: Cements which are made by burning impure limestones at a low temperature (insufficient to vitrify) which do not slake with water, but require to be ground in order to convert them into a hydraulic cement.
4. Portland cement: Hydraulic cements which are made by heating to incipient vitrification a mixture of argillaceous and calcareous substances, which product does not slake with water, but upon grinding forms an energetic hydraulic cement.
5. Puzzolan cement: Cements which are formed by incorporating slaked lime with a finely ground slag or volcanic ash.

[1]The Limestones of Maryland, with special reference to their use in the manufacture of cement: Special Publication Md. Geol. Survey, Vol. VIII, pt. 3, 1910, pp. 270-271.

The hydraulic limes are burned at a low temperature so that the resultant material will contain sufficient free lime to slake the entire clinker when water is added. The raw materials used in the manufacture of natural cements are burned to a higher temperature than the hydraulic limes, that is, to a temperature of 900-1,000 degrees centigrade, so that the carbon dioxide is driven off and the calcium and magnesium oxides combine with the argillaceous ingredients. The natural cements which contain a low content of argillaceous material are more nearly like the hydraulic limes, while those with a high content of silica and alumina more closely approach a Portland cement. The fine grinding and burning of Portland cement mixtures to incipient vitrification, followed by the fine grinding of the clinker, results in a cement entirely distinct from the hydraulic limes and natural cements. Portland cements set slower than natural cements and attain a higher tensile and crushing strength.

HYDRAULIC LIMES

Hydraulic limes occupy an intermediate position between what are known as simple limes, which show no hydraulic properties, and the complex cements, which are eminently hydraulic.

Hydraulic limes are made by burning siliceous or argillaceous limestones and at times a magnesian limestone (in the manufacture of feebly hydraulic limes) at a moderate temperature. While the raw materials used in the manufacture of hydraulic limes occur in this country, but little has been manufactured; however, a considerable quantity of hydraulic lime (including Grappier cements) is imported annually. Its characteristic light color, due to the low content of iron and soluble salts, has made it valuable, especially in interior work. The white cements which are now being manufactured in the United States are taking the place of the foreign hydraulic limes.

The hydraulic limes have been classified by Eckel[1] as: (1) eminently hydraulic limes; and (2) feebly hydraulic limes.

[1]Eckel, Edwin C., Cements, Limes and Plasters, 1907.

EMINENTLY HYDRAULIC LIMES

Raw materials.—The more important constituents of the limestones used in actual practice vary between the following limits:

	Per Cent.
Calcium carbonate ($CaCO_3$)	39 — 45
Silica (SiO_2)	13 — 17
Alumina (Al_2O_3) Ferric Oxide (Fe_2O_3)	0 — 3

The calcined stone must satisfy the following conditions: (1) it must contain sufficient free lime to slake the entire clinker when water is added. (2) Just sufficient free lime should be present to effect the disintegration of the clinker. (3) Free silica and alumina should not be present in the clinker.

Grappier cements.—These cements are made by the fine grinding of the underburned and overburned material resulting in the manufacture of eminently hydraulic limes. Lafarge non-staining cement made in France is a well known Grappier cement.

FEEBLY HYDRAULIC LIMES

Raw materials.—The more important constituents of the limestones used in actual practice vary between the following limits:

	Per Cent.
Lime and Magnesia ($CaO + MgO$)	45 — 48
Magnesia (MgO)	0 — 36
Silica (SiO_2)	5 — 8
Alumina (Al_2O_3) Ferric Oxide (Fe_2O_3)	4 — 7

The calcined stone contains a large excess of free lime, reducing the hydraulic property to almost nil.

Selenitic lime.—The feebly hydraulic limes form the base for the manufacture of selenitic limes, often known as Scott's cement, which consist primarily of lime (CaO) plus a small amount of sulphur trioxide (SO_3).

BURNING OF HYDRAULIC LIMES

Hydraulic limes are burned in kilns similar to the types used in the manufacture of simple limes. The argillaceous character of the rock necessitates a higher temperature in the kiln for complete decarbonation than a common high-calcium or dolomitic limestone.

THE EVOLUTION OF CEMENTS

It has been recognized since very early times that the product resulting from the burning of limestone when mixed with sand and water would produce an ordinary lime mortar. Lime mortar, however, would not harden under water. A material was needed for construction which would harden under water as well as in air and such a material now known as "natural cement" was used by the ancient Egyptians, the Greeks, and the Romans. Cummings[1] says:

> The fact is, that the history of natural rock cement reaches so far back into the early ages, that it is impossible to learn precisely the date of its first fabrication. But we do know that the ancient Egyptians made natural cement four thousand years ago which would set and harden under water. The Romans over two thousand years ago made most excellent natural cement, and used it in enormous quantities for sewers, water pipes, bathing fountains, piers, breakwaters, aqueducts, etc.

Many American writers have stated that the pyramids of Egypt were built of cement. In a letter from Athens, Greece, to the writer, Dr. D. M. Robinson[2] says:

> The pyramids of Egypt have no cement. They are built of blocks of native stone and the whole was covered with slabs of marble. The covering was long ago removed.

John Aspdin of Leeds, England, originated the name "Portland cement," which he applied to the resulting product made from limestone and clay after burning and grinding. This material, when it hardened, so closely resembled the stone from Portland, England, that he called it Portland cement. While the name Portland cement has remained, it is today a very different material from the cement made by Aspdin. It is generally thought that Aspdin made nothing more than an artificial Roman cement. Portland cement of today is a product, not an invention. It has been produced as the result of years of arduous investigations and has reached its present stage of perfection through the normal process of evolution from the simple to the complex.

[1]Cummings, Uriah, American Cements, 1898, p. 13.

[2]Professor of Greek, American School of Classical Studies, Athens, 1909-1910.

About the year 1818, a great deal of canal construction was going on in the United States and the engineers in charge were on the lookout for a material which would produce a natural cement. Canvas White, an engineer, found a natural cement rock near Chittenango, Madison County, New York, from which he manufactured a hydraulic cement used in the construction of the Erie canal. This marks the beginning of the cement industry in the United States. Natural cement was found in many other localities soon after this discovery was made by White.

At the time Aspdin made his so-called Portland cement in England in 1824, it had not been recognized that burning the material to incipient vitrification was essential. It is not known definitely at just what time it was recognized as essential for a Portland cement, however, it was known prior to 1859.

In 1875 the Coplay Cement Company, of Coplay, Penn., which company was at that time manufacturing a natural cement, was able through the experimental work of their President, David O. Saylor, to manufacture the first Portland cement made in this country.

Between the years 1875 and 1883, there was little advance in the manufacture of cements in America. Time was necessary to put the American cements on an equal footing with the European Portlands. Since 1890 the increase has been phenominal and the production and growth of natural and Portland cement in the United States can best be seen in the accompanying table No. 1.

NATURAL CEMENTS

Natural, Roman, and Rosendale cements are all derived from the same class of raw materials and the same general process of manufacture is used in their preparation. In the discussion which follows, they are all included under the general term natural cements.

Natural cements consist of those materials resulting from the burning and subsequent grinding of an argillaceous limestone containing natural compounds or mixtures of those compounds which, when combined, possess hydraulic properties. Natural cements are often referred to as hydraulic cements. All lime cements are hydraulic.

Raw Materials

The raw materials used in the manufacture of natural cements may be found throughout the sedimentary rocks from the Cambrian to the Recent, and they are widely distributed geographically. The raw materials contain from 15 to 30 or 40 per cent. of argillaceous material which combines with the lime, and also with the magnesia when present, to give the cement its hydraulic properties. Magnesia is not an objectionable constituent in a natural cement. It hydrates readily when it is calcined at a temperature below 1,000 degrees centigrade, while a highly burned rock containing a high content of magnesia hydrates slowly. The magnesia acts like lime combining with the argillaceous constituents to form silicates and aluminates. In the table below, analyses are presented of natural cement rocks from the more important localities in the Southern States.

Composition

The wide range of the composition of natural cements is due to differences in the character of the raw materials, in the methods of burning, and in the temperature attained, all of which cause differences in the chemical combination of the constituents and in their physical properties.

Analyses of Natural Cement Rocks in the Southern States

Location.		Silica (SiO_2)	Alumina (Al_2O_3)	Ferric Oxide (Fe_2O_3)	Lime (CaO)	Magnesia (MgO)	Alkalies (Na_2O+K_2O)	Sulphur trioxide (SO_3)	Phosphorus pentoxide (P_2O_5)	Clay bases (Al_2O_3, K_2O, Na_2O)	Carbon dioxide (CO_2)	Water (H_2O)
Maryland	Cumberland[1]	24.74	16.74	6.30	23.41	4.09	6.18	2.22	----	-----	22.90	----
Maryland	Hancock[2]	19.81	7.35	2.41	35.76	2.18	----	----	----	-----	31.74	
Maryland	Antietam[3]	15.97	7.59		23.72	15.60	---	0.71	.. ..	-----	34.82	
Virginia	Balcony Falls[4]	17.30	6.18	1.62	29.54	13.05	----	----	----	-----	34.17	
				74								
West Virginia	Shepherdstown[5]	15.89	5.58	1.00	52.74	19.06	4.92	0.31	0.12	-----	----	----
West Virginia	Cedar Cliff[6]	27.86	11.71	.72	40.74	13.95	1.30	----	----	-----	----	0.85
Kentucky	Louisville[7]	9.69	2.77	1.95	29.09	15.69	----	----	----	-----	40.14	
Georgia	Cement[8]	5.28	2.62		30.60	17.25	----	0.02	0.04	3.83	---------	
Georgia	Rossville[9]	6.52	0.96		47.98	1.25	----	----	tr.	2.58	40.71	
Georgia	Rossville[10]	22.93	4.16		33.80	0.45	----	0.03	0.02	10.43	28.18	

[1]Eckel, E. C., Cements, Limes and Plasters, 1907, p. 206.

[2]Ibid.

[3]Ibid, p. 213.

[4]Ibid, p. 212.

[5]Grimsley, Geo. P., Clays, Limestones, Cements W. Va. Geol. Survey, Vol. III, 1905, p. 500.

[6]Ibid, p. 503.

[7]"Crown Brand," Hansdale Mill, New Albany Cement Co. Analysis by W. A. Noyes, quoted by Siebenthal, 25th Ann. Rept., Ind. Dept. Geol. & Nat. Res., pp. 380-386.

[8]From strata of dolomitic limestone used at the present time.

[9]Limestone.

[10]Argillaceous limestone locally known as "cement rock."

[9] and [10] are burnt separately, then mixed and ground to produce a natural cement.

In the following table are presented analyses of the natural cements at the more important localities in the Southern states:

Analyses of Natural Cements in the Southern States

Location.		Silica (SiO_2)	Alumina (Al_2O_3)	Ferric oxide (Fe_2O_3)	Lime (CaO)	Magnesia (MgO)	Alkalies (K_2O,Na_2O)	Sulphur trioxide (SO_3)	Carbon dioxide (CO_2)	Water (H_2O)
Maryland	Cumberland[1]	25.70	12.28	4.22	52.69	1.44	----	----	----	----
Maryland	Hancock[2]	28.02	10.20	8.80	44.48	1.00	0.50	----	7.00	
Maryland	Antietam[3]	33.50	10.44	3.25	29.38	13.37	----	1.15	7.15	
Virginia	Balcony Falls[4]	25.15	8.00	3.28	49.53	13.78	----	----	0.26	
West Virginia	Shepherdstown[5]	33.42	10.04	6.00	32.79	9.59	0.50	----	----	----
West Virginia	Cedar Cliff[6]	27.86	11.71	2.72	40.74	13.95	1.30	----	----	0.85
Kentucky	Louisville[7]	21.10	7.50		44.40	7.00	.80	----	11.18	1.16
Georgia	Cement[8]	22.58	7.23	3.35	48.18	15.00	----	----	3.66	
Georgia	Cement[9]	19.60	11.60		48.96	18.14	----	----	----	----
Georgia	Rossville[10]	25.89	6.20	1.99	34.09	1.59	----	0.50	----	----

[1]Daw, A. W., Analyst, Min. Ind., Vol. 6, p. 96.
[2]Cummings, Uriah, American Cements, 1898, p. 36, Round Top hydraulic cement.
[3]Richardson, C., Analyst, Brickbuilder, Vol. 6, p. 229.
[4]Cummings, Uriah, American Cements, 1898, p. 36, James River hydraulic cement.
[5]Ibid, p. 35, Shepherdstown hydraulic cement.
[6]Attix, J. C., Analyst, W. Va. Geol. Survey, Vol. III, 1905, p. 503.
[7]Mineral Industry, Vol. I, p. 50.
[8]Cummings, Uriah, American Cements, 1898, p. 35.
[9]Bowron, W. M., Analyst, Eckel, E. C., Cements, Limes & Plasters, 1907, p. 253.
[10]Clark, C. M., Analyst, Supplied by Chickamauga Cement Co.

MANUFACTURE

Winning the raw materials.—The raw materials are quarried in open pits or mined. The majority of the materials used in the manufacture of natural cements, with the exception of those in the Lehigh district of Pennsylvania and New Jersey, occur in beds six to eight feet in thickness, and on account of the structural conditions and the usual considerable thickness of overlying rocks, are most economically secured by mining.

The argillaceous limestone should be broken into pieces of approximately the same dimensions. The more satisfactory method is to pass the rock through crushers. When the rock is fed into the kiln in uniform sizes a better utilization of the kiln space is secured and a greater uniformity of burning results. When materials of different size are fed into the kiln the smaller masses will be overburned before the larger ones are thoroughly calcined.

Types of kilns.—Argillaceous limestones used in the manufacture of natural cements can be burnt either in vertical continuous feed kilns or in rotary kilns similar to those used in the manufacture of Portland cement. The general type is the vertical continuous feed kiln much like the ordinary lime kiln, but usually larger. The average size consists of a vertical cylinder ten feet in diameter and 24 feet high, the lower seven feet is funnel shaped, tapering to three feet in diameter and narrowing to a neck through which the calcined rock is drawn. The coal, which consists of either an anthracite or a high grade bituminous variety, is either fed into the kilns with the argillaeous limestone or in alternate layers. This method of adding the fuel necessarily causes irregularity in burning, and the raw materials in close contact with the fuel will probably be overburnt before the limestone that is not in direct contact with it is thoroughly calcined. This difficulty could be overcome and the quality of the cement greatly improved by burning the fuel in furnaces arranged at the bottom and around the vertical kilns.

Burning.—The changes which take place in burning an argillaceous limestone consist first in the driving off of carbon dioxide from the calcium and magnesium carbonates and the combination of the resulting calcium and magnesium oxides with the argillaceous materials to form silicates. Magnesium carbonates decompose at a lower temperature than calcium carbonates. Investigations on the temperature of burning of raw materials for natural cements were carried on by Bleininger[1] and he came to the following conclusions:

> The best temperature for burning calcareous Roman cements is 1,000 degrees C. Below this temperature hydraulicity is not fully developed, above

[1]Bleininger, Albert Victor, Manufacture of Hydraulic Cements: Geol. Survey of Ohio, 4th ser., Bull. 3, pp. 184, 185.

it a non-hydraulic compound is evidently produced; whether on going still higher hydraulicity is restored has not been determined, but seems doubtful. * * * *

The proper burning temperature of dolomitic Roman cements is about 950 degrees C., and should be lower rather than higher.

Natural cement rock in the Lehigh district is crushed to a pea size or smaller and burned in the rotary kiln. The length of burning is considerably shorter than the time required to burn the rock in the upright kiln. The clinker is burned uniformly and as a result there is no underburned or overburned rock, and after the clinker is crushed and pulverized it results in a superior quality of cement.

Crushing and grinding.—The calcined "cement rock," as it comes from the vertical kilns, consists of hard and soft material. These materials are separated, and at some plants the hard calcined rock is discarded while at others the soft clinker is thrown away.

The calcined rock first undergoes a preliminary grinding. The vertical cracker known as the coffee mill is the type which has been most used in the past. The finely ground dust passes through screens and is conveyed to the packing house while the coarser material is carried to the mill for fine grinding. The buhrstone and the rock emery mills were the type in general use for fine grinding until the last decade.

The more progressive manufacturers of natural cement today crush the calcined rock in a disintegrater or Kent mill and then pass it to a tube mill for the fine grinding. The advantages of the tube mill are: (1) fineness of the product, usually 90 to 95 per cent. through a 100-mesh sieve; (2) its large capacity; (3) no screening necessary; (4) repair of mill and wear of pebbles very small; (5) eliminating the troublesome attention required in the dressing of stones which is necessary in the buhrstone and rock emery mills.

Until the last decade the grinding of calcined cement rock was seldom carried further than 95 per cent. through a 50-mesh sieve. The manufacturer now realizes that fine grinding has the effect of increasing the sand-carrying capacity of the cement, making its strength test greater in mortars and the cement more sound.

THE NATURE OF PORTLAND CEMENT

In the beginning of the modern practice of the manufacture of cements it was observed that limestones containing argillaceous matter possessed hydraulic properties when calcined. The early makers of cement attributed the hydraulic properties to the presence of the clay.

The French were the first to investigate extensively the nature of cements and while there were also many other works in Germany, England, Russia, United States, and elsewhere, it is only possible here to give a brief summary of a few of the more important investigations.

Vical made known the results of his investigations in 1818; however, his experiments were confined chiefly to hydraulic lime and puzzolan.

Le Chatelier[1] was the first to make a mineralogical (microscopic) examination into the nature of Portland cement. He considered tricalcium silicate ($3CaO.SiO_2$) the active element of cements, and found also what he considered to be tricalcium aluminate.

Richardson in 1902 illustrated the crystalline character of Portland cement by means of micro-photographs and came to the conclusion that it is a solid solution. In 1904[2], after carrying on the most extensive microscopic investigation yet attempted, he arrived at the conclusion that cement clinker consists of two solid solutions, i. e., tricalcium aluminate ($3CaO.Al_2O_3$) dissolved in tricalcium silicate ($3CaO.SiO_2$) and dicalcium aluminate ($2CaO.Al_2O_3$) dissolved in dicalcium silicate ($2CaO.SiO_3$).

W. B. and S. B. Newberry[3], making a study of synthetic compounds, agreed with Le Chatelier that tricalcium silicate ($3CaO.SiO_2$) was the active element in cements; however, they considered the alumina present as dicalcium aluminate ($2CaO.Al_2O_3$).

Day and Shepherd[4] of the Geophysical Laboratory of the Carnegie Institute were the first to study the synthetic silicates both by the aid of petrologic and physico-chemical methods. They first carefully

[1]Annales des Mines, 1887.

[2]Papers, Ass'n Amer. Portland Cement M'f'rs, June 15, 1904.

[3]The Constitution of Hydraulic Cement: Jour. Soc. Chem. Inds., Vol. XVI, XI.

[4]The Lime Silica Series of Minerals: Jour. Am. Chem. Soc., Vol. XXVIII. No. 9, Sept. 1906, pp. 1089-1114.

studied lime (CaO) and silica (SiO_2) separately. They observed that calcium oxide is so refractory that with the present pyrometers it is not possible to make a satisfactory determination of its melting point. They succeeded by direct experiment upon pure silica in establishing the fact that tridymite and not quartz is the stable crystalline form of silica for all temperatures above 1,000 degrees. The further study of silica established many important facts. Having investigated the two component minerals of the lime-silica series they began the study of their relation to each other in mixtures of various proportions. After extensive chemical and microscopic work these investigators were able to reach a conclusion that tricalcium silicate ($3CaO.SiO_2$) does not exist. Their remarks concerning the former belief that it was the important constituent of Portland cement are as follows[1]:

A moment's consideration should suggest that there is no real necessity for assuming the existence of the tricalcium silicate in order to explain the nature of Portland cement. It is a system of at least three components with a great number of possibilities. The real difficulty appears to have been that crystalized lime is relatively inert and does not readily give the reactions common to ordinary lime, consequently the tests which were thought to demonstrate the absence of free lime in these preparations have proved very misleading. For example, we have found that crystals of lime are but very slowly attacked by water (See page 1,094). Another argument which is freely offered, that there can be no free lime present "because if free lime is added the cement dusts spontaneously" is obvious fallacy. Free lime does not cause the dusting and if it did the fact that the addition of free lime caused dusting would be no proof that none was present.

In the microscopic sections studied, every preparation containing more than 65 per cent. CaO (orthosilicate composition) an excess of free lime could always be positively identified. The tricalcium silicate composition was fused and cooled in various ways and free lime was always found present in quantity and further examination of sections made by other workers always showed free lime present, so they were forced to the conclusion that no tricalcium silicate existed.

Burchard says[2]:

"The most important purely scientific studies of the constitution of Portland cement clinker have been carried on during the last few years by Day,

[1]Ibid, note 3, pp. 1106-1107.

[2]The Cement Industry in the United States in 1910: Advance Chapter from Mineral Resources of the United States, 1911.

Wright, Shepperd, and Rankin in the Carnegie Geophysical Laboratories, Washington, D. C.[1] In the more recent work it has been found that a small addition of alumina brings out the tricalcic silicate, but it appears to have peculiar properties and limitations. For instance, the tricalcic silicate has been found to be unstable at its melting temperature and for some degree below, so that a melt of this compound invariably crystalizes on cooling to orthosilicate and lime. In the presence of alumina, or even alone, if held for a sufficient time at temperatures in the vicinity of 1,800° the orthosilicate and lime combine to form a new compound with new and independent properties, homogeneous within the limits above noted. As the result of about 800 observations, it has been concluded by these investigators that tricalcic silicate belongs to that class of compounds which form by reaction between the solid components, but which decompose before the melting temperature is reached; that is, they are wholly unstable in contact with the melt. The reaction is, therefore, reversible and would be expressed as follows: $3CaO . SiO_2 \rightleftarrows 2CaO . SiO_2 + CaO$.

PORTLAND CEMENT

Portland cement is derived from an artificial mixture of calcareous and argillaceous materials consisting essentially of lime, silica, alumina, and iron oxide, which, when brought together in certain definite proportions, finely ground, and burnt to incipient vitrification, result in a fused mass known as clinker, which when pulverized to a fine powder has the property of setting under water and attaining a high compressive and tensile strength.

Raw Materials

The following raw materials are used in the manufacture of Portland cement:

Calcareous materials	*Argillaceous materials*
High-calcium limestones or marbles	Clays, shales, or slates
	Clays
High-calcium limestone with argillaceous limestone	Slags
Marls	
Limestones	

[1]Day, A. L., Shepherd, E. S., and Wright, F. E., The lime-silica series of minerals: Am. Jour. Sci., 4th ser., Vol. 22, October, 1906, pp. 265-302. Shepherd, E. S., Rankin, G. A., and Wright, F. E., The binary systems of alumina with silica, lime, and magnesia: Am. Jour. Sci., 4th ser., Vol. 28, October, 1909, pp. 293-333. Shepherd, E. S., and Rankin, G. A., Preliminary report on the Ternary system $CaOAl_2O_3SiO_2$. A study of the constitution of Portland cement clinker, with optical study by F. E. Wright: Jour. Ind. and Eng. Chem., April, 1911, pp. 211-227.

The essential ingredients used in the manufacture of Portland cements are all found combined with one another and with other constituents in calcareous or argillaceous materials. While the essential constituents all occur in nature in the uncombined state, with the exception of lime, they are never used commercially in the uncombined form, except in small quantities when the raw materials are deficient to some slight extent in any one of the essential elements.

The raw materials from which Portland cement may be made in North Georgia are, chiefly: (1) High-calcium limestones or marble and clays, shales or slates; and (2) high-calcium limestone and argillaceous limestone.

Calcium carbonate, which is the source of the lime, is the predominating constituent in the calcareous materials, while silica and alumina form the chief constituents of the clays, shales or slates. Iron oxide is always present in both the calcareous and argillaceous materials and greatly facilitate their fluxing in the kiln; however, in the manufacture of a white Portland cement iron is not desirable and the alkalies are used to promote the fluxing.

CALCAREOUS MATERIALS

The calcareous materials should satisfy the following physical and chemical conditions:

1. The lithologic character of the calcareous materials should be uniform over a unit of sufficient thickness for economic development.

2. Concretions of iron in any form; uncombined silica in the form of chert, flint, quartz veins, or when combined in the minerals tremolite and diopside, is seriously objectionable.

3. It is always essential that the magnesia content be low, so that after the argillaceous material has been added the total quantity of magnesia does not exceed 5 per cent. The magnesia content of limestone varies from a fraction of one per cent. to the true dolomites. It is one of the most important factors to be taken into consideration in the location of the calcareous materials.

4. The argillaceous content consisting of silica and alumina should

not be in sufficient quantity to interfere with the desired silica-alumina ratio in the finished product.

5. To obtain a white Portland cement the percentage of ferric oxide in the calcareous material must not exceed 0.2 per cent.

6. The alkalies are usually contained in very small amount in the high-calcium and argillaceous limestones and need not be considered; however, they are sometimes present in objectionable quantity in the marls.

7. The sulphur content should not exceed .5 per cent.

8. The phosphorus content seldom needs to be considered, except in the marls. It should not exceed .02 per cent.

High-calcium limestones.—High-calcium limestones may be holo-crystalline or crypto-crystalline in their physical character. The holo-crystalline limestones contain a very high percentage of calcium carbonate and are usually low in impurities. The holo-crystalline limestones, or marbles are usually massive and often the recrystallization has been so complete that all traces of the original bedding have been obliterated.

The crypto-crystalline limestones in places occur in massive beds and are usually extremely dense. They are most abundant in the Appalachian Valley region, and are an important source of lime for the manufacture of Portland cement. The content of calcium carbonate is usually lower than in the holo-crystalline limestones with a greater percentage of impurities, consisting chiefly of silica, alumina, and iron oxide, while they are frequently associated with beds containing much magnesium carbonate.

Argillaceous limestones.—The argillaceous limestones are usually dense, non-crystalline in physical character and high in clayey impurities. When the silica, alumina, and iron oxide consist of 20 to 25 per cent. and the calcium carbonate consists of about 75 per cent. of the rock, it is then known as an argillaceous limestone. The argillaceous limestones form the most important source of both the calcareous and argillaceous materials used in the manufacture of Portland cement in the United States. The argillaceous materials are supplied in these rocks and for this reason they are often classified with the argillaceous rocks; however, the high content of calcium carbonate places them among the limestones. It is usually necessary to add a small percentage of very high-calcium limestone to these argillaceous limestones in order to procure a suitable mix for Portland cement, although they are also the most important source of the calcareous materials.

Marls.—The marls are extensively used in the manufacture of Portland cement. High-calcium marls and argillaceous marls are usually well suited for making cement and are generally characterized by a low content of magnesia. The marls are seldom consolidated and the first cost of crushing is unnecessary. As marls are not found in North Georgia they will not be further discussed.

ARGILLACEOUS MATERIALS

The argillaceous materials should satisfy the following physical and chemical conditions:

1. The lithologic character of the argillaceous material should be uniform over a sufficient thickness for economic development.

2. Concretions of iron in any form, uncombined silica in the form of flint and quartz veins are seriously objectionable.

3. The silica content should be from 60 to 70 per cent. Argillaceous materials deficient in silica can be used with free silica in the form of pure finely ground sandstone; however, it is always most desirable to add the silica in combined form.

4. It is always essential that the magnesia content be low so that the combined mix of calcareous and argillaceous material does not exceed 5 per cent.

5. In the manufacture of a white Portland cement the clay must be sufficiently low in ferric oxide (Fe_2O_3) so that the combined material contains less than 0.5 per cent.

6. The content of sulphur should not exceed 0.5 per cent.

The following relation of the chemical ingredients of the argillaceous material is preferable:

The ratio of the silica to the alumina should range between 3 to 1 and 4 to 1. The sum of silica and alumina should not exceed 86 per cent. The sum of the alumina and iron oxide should not be more than one-half the silica. The closer the sum of the alumina and iron oxide approaches one-third the silica the better.

The presence of iron oxide (Fe_2O_3) is desirable in the manufacture of the gray cements to facilitate the fluxing; however, it should not be in such quantity as to cause the iron oxide (Fe_2O_3) content of the finished product to exceed 4 per cent.

The argillaceous materials consist of clays, shales and slates and may all be of similar chemical composition, but differing in their physical characteristics.

Clays.—The residual clays of North Georgia are seldom suitable for use in the manufacture of Portland cement. The residual clays in the Appalachian Valley region, which are derived from high-calcium limestones and shales, may be of sufficient thickness locally to be available.

Shales and slates.—The shales and slates consist of fine-grained, consolidated muds and usually contain less than 5 per cent. of calcium carbonate. Shales and slates used in the manufacture of cements are known as normal shales and slates when they contain less than 5 per cent. of calcium carbonate, while they are known as calcareous shales and slates when they contain more than this amount of calcareous material.

Chemical Ingredients

The more important and essential chemical constituents, which compose the mixture in the manufacture of Portland cement, are lime, silica, alumina, and iron, while the less important or accessory constituents are magnesia, the alkalies, sulphur, water, carbon dioxide, and at times the following substances: phosphorus pentoxide, titanic oxide, strontium oxide, ferrous oxide, and manganous oxide, all of which occur in such small quantity that they can be neglected.

The chemical analyses of a cement alone does not give us any information regarding the combinations in which the chemical elements occur in the cement. Two cements containing essentially the same chemical analysis may differ to a very considerable extent in their physical properties. Definite proportions of the essential ingredients are necessary to produce a Portland cement that will satisfy the standard physical tests.

Chemical Interpretation

In order to obtain a conception of the nature of Portland cement it is necessary to be familiar with the chemical constituents of which it is composed. The more important elements contained in cements, their symbols and atomic weights are given in the following table[1]:

Symbols and Atomic Weights of Elements

Element	Symbol	Atomic Weight
Hydrogen	H	1.01
Oxygen	O	16.00
Silicon	Si	28.40
Aluminum	Al	27.10
Iron	Fe	55.90
Calcium	Ca	40.10
Magnesium	Mg	24.36
Carbon	C	12.00
Sulphur	S	32.06

The analyses of the raw materials and cements are always given in the form in which these elements are combined.

The more important compounds which constitute a Portland cement mixture are:

Calcium carbonate	($CaCO_3$)
Magnesium carbonate	($MgCO_3$)
Silica	(SiO_2)
Alumina	(Al_2O_3)
Oxide of iron	(Fe_2O_3)
Alkalies	(Na_2O, K_2O)

The chemical interpretation of these compounds is as follows:

The molecular weight of any of these compounds is equal to the sum of the atomic weight of the elements constituting the compound. The percentage of any element contained in the compound is obtained by adding the atomic weights and dividing the result into the atomic

[1]Jones, Harry C., Elements of Inorganic Chemistry, 1908, pp. 121-122.

weight of any one element. For example, take calcium carbonate ($CaCO_3$), which may be considered as made up of lime (CaO) and carbon dioxide (CO_2):

One atom of Ca has an atomic weight of.............. 40.1
One atom of C has an atomic weight of................ 12.0
Three atoms of O have an atomic weight of 3×16 or.. 48.0

The molecular weight of the calcium carbonate is equal to the sum of the atomic weights of the elements constituting the compound. The molecular weight of the lime (CaO) equals the sum of the automic weights of its elements, that is, 56.1. In order to obtain the percentage of any one element in a compound divide the atomic weight of that element by the sum of the elements contained in the compound. For instance:

$$\left.\begin{array}{l}\text{Ca has a molecular weight of } 40.1\\ \text{O has a molecular weight of } 16.0\end{array}\right\} 56.1$$

Percentage of calcium (Ca) in lime (CaO), $40.1 \div 56.1 = 71.4$
Percentage of oxygen (O) in lime (CaO), $16.0 \div 56.1 = 28.5$

If the percentage of lime (CaO) is given and the percentage of calcium carbonate ($CoCO_3$) is desired divide the percentage of lime (CaO) by .56 and if the calcium carbonate ($CaCO_3$) is given and the lime (CaO) is desired multiply the percentage of calcium carbonate ($CaCO_3$) by .56.

Calculation of Cement Mixtures

In calculating mixtures of calcareous and argillaceous materials for the first time it is necessary to rely entirely on the chemical analyses of the untried materials. It has not yet been found possible to scientifically express the composition of Portland cement in a mathematical formula, so it is therefore impossible to arrive at a definite conclusion as to just what the ultimate analyses of the cement of any local raw materials should be except through experiment. It is possible to arrive at a close approximation to the ultimate composition of the cement by the use of a formula ($3CaO.SiO_2 + 2CaO.Al_2O_3$) presented by Prof. Newberry for the constitution of Portland cement. In Prof. Newberry's calculation the percentage of iron oxide is added to the percentage of alumina, the total being considered as alumina, while he does not take into account the magnesia. Eckel presents a formula which differs from Newberry's only in the fact that the magnesia and the iron are allowed for. The various steps in the proportioning of a cement mixture as given by Eckel[1] are:

Operation 1. Multiply the percentage of silica in the clayey material by 2.8, the percentage of alumina by 1.1, and the percentage of iron oxide by 0.7; add the products; subtract from the sum thus obtained the percentage of lime oxide in the clayey material plus 1.4 times the percentage of magnesia and call the result *n*.

Operation 2. Multiply the percentage of silica in the calcareous material by 2.8, the percentage of alumina by 1.1, and the percentage of iron oxide by 0.7; add the products and subtract the sum from the percentage of lime oxide plus 1.4 times the percentage of magnesia in the calcareous material, calling the result *m*.

Oeration 3. Divide *n* by *m*. The quotient will be the number of parts of calcareous material required for one part of clayey material.

Example. Assuming that materials of the following composition are in use the operation would be as follows:

	Clay	Limestone
Silica (SiO_2)	62.2	2.4
Alumina (Al_2O_3)	16.1	2.0
Ferric oxide (Fe_2O_3)	4.2	0.3
Lime (CaO)	1.6	50.2
Magnesia (MgO)	1.2	1.5
Sulphur trioxide (SO_3)	1.7	0.6
Alkalies (Na_2O, K_2O)	0.8	0.4
Water, carbon dioxide, etc.	12.2	42.6

Operation 1, clay:

Silica	$\times$ 2.8 = 62.2 $\times$ 2.8 =	174.16
Alumina	$\times$ 1.1 = 16.1 $\times$ 1.1 =	17.71
Iron oxide	$\times$ 0.7 = 4.2 $\times$ 0.7 =	2.94
		194.81
Lime	$\times$ 1.0 = 1.6 $\times$ 1.0 =	1.60
Magnesia	$\times$ 1.4 = 1.2 $\times$ 1.4 =	1.68
		3.28

194.81 — 3.28 = 191.53 = n.

Operation 2, limestone:

Silica	$\times$ 2.8 = 2.4 $\times$ 2.8 =	6.72
Alumina	$\times$ 1.1 = 2.0 $\times$ 1.1 =	2.20
Iron oxide	$\times$ 0.7 = 0.3 $\times$ 0.7 =	0.21
		9.13

[1]Cements, Limes and Plasters, 1907, pp. 392-393.

AN OUTCROP OF WHITE MURPHY MARBLE AT THE PERSEVERENCE QUARRY, 2 MILES EAST OF JASPER, PICKENS COUNTY, GEORGIA

Lime	$\times 1.0 = 50.2 \times 1.0 =$	50.20
Magnesia	$\times 1.4 = 1.5 \times 1.4 =$	2.10
		52.30

$$52.30 - 9.13 = 43.17 = m.$$

Operation 3:

$$\frac{n}{m} = \frac{43.17}{191.53} = 4.44 \text{ parts of limestone to be used for each part of clay by weight.}$$

It must be recollected that the value given by the above formula represents the highest amount of lime theoretically possible under the best possible conditions of fine grinding and thorough burning. Even in the best run plants these conditions cannot be attained in practice, and in a trial run either in a test kiln or in actual plant it is foolish to attempt to reach this limit. The limestone shown by the formula should therefore be reduced in order to get safe results. A reduction of 10 per cent. will probably be satisfactory. In the example given above this would work out as follows:

4.44 = parts of limestone (to 1 of clay) allowed by formula
0.44 = 10 per cent. reduction for safety.

4.00 = parts of limestone (to 1 of clay) to be actually used.

Transportation Facilities and Markets

The first essential specification in the location of a Portland cement plant is that it shall have adequate transportation facilities. A plant should be located if possible either on a water route and a railroad or in close proximity to two railroads. A location with respect to an adequate market is another essential factor.

Conditions Affecting Development

Determination of quality.—In the search for raw materials suitable for the manufacture of a Portland cement it is desired to secure beds of definite and uniform chemical composition over lithologic units of sufficient thickness to be economically available. Limestones and dolomites cover wide areas and are often of great thickness. Limestones containing more than 5 to 6 per cent. of magnesia can not be successfully used in the manufacture of a Portland cement. The relative content of magnesia in the calcareous rocks can be told with considerable accuracy in the field. Dolomites and dolomitic limestones can always be detected in the field by the fact that when they are treated with dilute hydrochloric acid they effervesce with difficulty. Magnesian limestones containing from 5 to 15 per cent. of magnesia effervesce more slowly than the high-calcium limestones. When high-calcium limestones are treated with dilute hydrochloric acid they are entirely dissolved.

In the search for a limestone available for a cement, it is first desirable to select a section where the limestone is best exposed in the formation and to make a careful study of the character of each lithologic unit and to collect samples for chemical analyses from every inch of each unit. The physical character of the calcareous rock is usually a criterion of the chemical composition and when a thorough knowledge of the whole formation is obtained any definite bed can be recognized when exposed and its chemical composition known with sufficient accuracy to justify a careful sampling for a definite accurate knowledge of the rock at any point.

In the search for argillaceous materials it is also essential to be familiar with the relation of lithology to chemical character. The magnesia content in the argillaceous materials is usually low and the most important factors to be taken into consideration are the silica-alumina ratio, the content of iron, and the physical character of the argillaceous material.

Determination of quantity.—The determination of the quantity of raw materials is an essential factor in the location of a Portland cement plant. A plant should not be built unless there is sufficient raw material present to supply a mill with a capacity of 2,000 barrels a day for at least 25 years. The term so often used "the indications are that the materials are inexhaustible" is sufficient proof that the author of such a statement knows but little of the occurrence of these materials. What is desired are the facts, and nothing but the facts should be considered concerning raw materials.

The horizontal length and width of the outcrop and the depth to which it can be commercially won can be easily ascertained. The number of cubic feet of stone can be obtained by multiplying these values, which, multiplied by the weight of one cubic foot of the material in pounds, divided by 2,000 (2,000 pounds to the ton) will give the available tonnage.

Relation to topography and drainage.—The location of the plant in its relation to topography and drainage has an important bearing on the cost of manufacture of the cement. If the quarries of the calcareous and argillaceous materials are so situated that the raw materials can reach the plant and pass through each process to the final bagging and packing by means of a gravity system, it is needless to say it can be done at considerable less cost than at the mill where the raw materials are raised from below water level to the mill, and raised and reraised through the many processes to which it is necessary to pass the raw materials. Quarries located above water level can be drained with ease and thorough drainage greatly facilitates the quarrying of the rock in wet weather.

Overburden.—The thickness and character of the overburden, if present, should be carefully ascertained. The writer has seen quarries started where in a very short time the amount of the overburden will reach a thickness, due to the dip of the rocks, that will prevent the commercial winning of the raw materials.

Location with respect to fuel supply.—A Portland cement plant must be located in the close proximity to a fuel supply. The fuel consumption represents one of the largest items in the cost of manufacture. Great water-power developments may furnish power for the operation of the machinery; however, it will be necessary to use coal as a fuel in the burning of the raw materials in the rotary kiln. While the high-carbon coals, that is, anthracites and semi-bituminous coals, give higher temperatures than the bituminous coals they are not as satisfactory as the bituminous coals for use in the rotary kiln. When the high-carbon coals are pulverized and blown into the kiln combustion takes place more slowly than when pulverized bituminous coal is used.

The specifications for a coal to be used in the rotary kiln for the burning of the raw materials to incipient vitrification are as follows:

1. The volatile matter should be high, preferably between 30 and 40 per cent., so that the maximum temperature is produced in the

rotary kiln about 10 feet from the lower end of the kiln. When the maximum temperature occurs too far from the lower end of the kiln it causes "ringing" and it makes it difficult for the burner to watch the vitrification of the clinker, through a knowledge of which he regulates the burning.

2. The fixed carbon should preferably range between 50 and 60 per cent.

3. The lower the content of sulphur in the coal the better. When the content of sulphur is more than 1 per cent. it is liable to cause many difficulties.

4. The lower the content of ash the better. A high content of ash not only decreases the heating power of the coal, but a considerable portion of the ash is contained in the cement mixture, and thus ash in excess contaminates the finished cement.

COALS ACCESSIBLE TO NORTH GEORGIA

Chattanooga district.—The coals available for use in the manufacture of Portland cement in North Georgia can be obtained from the Chattanooga district, containing portions of the three states of Georgia, Alabama, and Tennessee.

Hayes[1] defines the limits of the Chattanooga district as follows:

> The Chattanooga district includes the territory from the Emory River southward a short distance into northern Georgia and Alabama. It includes the Sewanee basin, which is a portion of the Cumberland Plateau, the Walden basin, separated from the Cumberland Plateau on the west by Sequatchie Valley, and the Lookout basin, which occupies the northern portion of the Lookout Mountain syncline.

Analyses of coals from the Tennessee portion of the Chattanooga district[2] are given below.

[1]Hayes, C. W., 22nd Ann. Rept. U. S. Geol. Survey, Pt. III, 1902, pp. 234.
[2]Shiflett, R. A., Mineral Resources of Tennessee for 1909, pp. 35-36.

Chemical Analyses of Coals from Tennessee Portion of Chattanooga District

County and Operating Company	Name of Coal	Thickness	Fixed Carbon	Volatile matter	Ash	Moisture	Sulphur
		ins.	per ct.	per ct.	per ct.	per ct.	per ct.
BLEDSOE COUNTY—							
Atpontley Coal Co	Sewanee	34	63.57	28.17	7.10	1.61	1.15
CUMBERLAND COUNTY—							
Clear Creek Coal Co	Isoline	44	53.86	42.20	2.21	1.73	1.47
Fall Creek Colliers	Upper Sewanee	50	63.70	30.76	4.82	0.72	0.40
Renfro Coal & Coke Co	Sewanee	42	68.27	28.32	2.32	1.03	0.06
Waldensia C'l. & C. Co	Upper Sewanee	42–60	64.50	29.55	5.50	0.45	0.54
GRUNDY COUNTY—							
Flat Branch Coal Co	Sewanee	34	66.80	24.57	7.43	1.20	0.66
Nunely Ridge Coal Co	Sewanee	36	61.68	29.73	7.65	1.04	------
Sewanee Fuel & Iron Co	Sewanee	30	59.88	31.32	7.50	1.30	0.85
Ten. Consol'd Coal Co	Sewanee	42	61.68	29.73	7.65	1.04	------
HAMILTON COUNTY—							
Montlake Coal Co	No. 10	36	64.92	26.34	8.74	------	0.84
New Soddy Coal Co. (Big S)	No. 9	30	61.22	27.40	10.11	1.27	0.47
New Soddy Coal Co. (Soddy)	No. 7	27	60.44	29.18	7.16	2.10	1.12
Sale Creek Coal Co	No. 2	42	60.29	31.27	7.02	1.42	0.60
MARION COUNTY—							
Battle Creek C'l & C Co	Battle Creek	24–312	59.77	34.74	5.12	0.02	0.17
New Etna Coal Co	Kelly	32	73.12	20.26	4.70	------	------
Nunley Ridge Coal Co	Sewanee	48	61.68	29.73	7.65	1.19	0.73
Ten. Consol'd Coal Co	Sewanee	36	60.60	30.30	6.00	1.04	------
RHEA COUNTY—							
Fox Coal Co. 1	No. 2	240	60.57	34.23	3.77	1.43	0.51
Fox Coal Co. 2	No. 5	30	60.24	28.97	9.45	1.34	0.82
Dayton Coal & Iron Co	Richland	22	59.20	31.00	12.40	------	0.99
ROANE COUNTY—							
Roane Iron Co	Sewanee	54	53.76	30.13	15.96	------	0.61
SEQUATCHIE COUNTY—							
Southern Steel Co	Sewanee	48	58.85	29.50	10.55	1.10	0.86
WHITE COUNTY—							
Bon Air Coal & Iron Co Ravenscroft, Mine	Bon Air	36	57.00	37.00	4.90	1.10	------
Bon Air Coal & Iron Co Bon Air, Mine	No. 3	54	57.50	33.00	7.50	------	2.00
Clifty Creek Coal Co	Sewanee	48	------	------	------	------	------

Georgia Coals.—The commercial coal deposits of Georgia occur only in Sand and Lookout mountains in Walker, Chattooga and Dade counties.

Lookout and Sand mountains structurally consist of shallow synclines separated by the Lookout Valley anticline. The base of these mountains consists of the Bangor limestones immediately above which occurs the Lookout sandstones and shales. The coals worked in the vicinity of Coal City in Sand Mountain occur in what are known as the lower coal measures, that is, in the Lookout sandstones and shales. The Walden formation lies stratigraphically immediately above the Lookout formation and carries the Sewanee coal. Only a comparatively small remnant of this formation remains on Lookout Mountain and forms what is locally known as Round Mountain.

Chemical Analyses of the More Important Coals of Georgia

Name of Coal	Location of Mine	Moisture	Fixed carbon	Volatile matter	Ash	Sulphur	Phosphorus	Analyst or authority
Suwanee[1]	Durham, Walker County	.....	79.100	16.030	4.810	0.360	0.007	Gustave Bedell, Chattanooga,
Sewanee[2]	Durham, Walker County	0.615	75.956	21.011	1.940	0.470	.....	A. S. Hewitt, New York.
Tatum[3]	Rock Creek Gulch, Walker County	1.020	75.980	20.850	1.440	0.760	0.007	N. P. Pratt Laboratory, Atlanta.
Rising Fawn[4]	Rising Fawn, Dade County	.....	75.756	19.046	4.840	0.786	0.002	A. S. Hewitt, New York.
Raccoon[5]	Cole City, Dade County	1.150	60.120	24.850	13.880	1.510	.....	N. P. Pratt Laboratory, Atlanta.

[1]Spencer, J. W., Geology of the Paleozoic Group of Georgia and Resources Geol. Survey of Ga., 1893, p. 258.

[2]Ibid, p. 258.

[3]McCallie, S W., Coal Deposits of Georgia: Geol. Survey of Ga. Bull. 12, 1904, p. 42.

[4]Average of three analyses, Spencer, J. W., Geology of the Paleozoic Group of Georgia and Resources: Geol. Survey of Ga., 1893, p. 259.

[5]McCallie, S. W., Coal Deposits of Georgia: Bull. Geol. Survey of Georgia No. 12, 1904, p. 90.

Correlation of the coal beds of Georgia with one another and with the coal beds occuring in similar formations in Tennessee and Alabama have been attempted on lithologic grounds by many workers; however, they have hardly been more than conjectures. Prof. S. W. McCallie, in speaking of the correlation of the Georgia coals aptly remarks[1]:

The only solution to the question of correlating the coal seams of the upper coal measures of Lookout Mountain with the coal seams elsewhere, seems to lie in the paleontological evidence furnished by the associated shales. Many of these shales teem with plant remains, which, if properly studied, would, no doubt, furnish valuable aid in correlating the various coal seams of Sand and Lookout mountains. Until such evidence is obtained no correlating, of any scientific value, is likely to be worked out.

Analyses of Coals of Georgia by Dr. William Henry Emerson[2]

	Carbon 1	Hydrogen 2	Water 3	Sulphur 4	Nitrogen 5	Ash 6
I	85.75	4.63	.88	.79	1.44	3.17
II	86.97	4.44	1.06	.62	1.25	2.00
III	79.41	4.60	.93	.88	1.39	9.05
IV	85.07	4.48	.77	.88	1.50	3.42
V	84.32	4.72	1.21	.78	1.66	4.20

	Calculated heating value 7	Colorimeter 8	Difference 9	Difference per cent. 10	Heating value per gram of combust'n 11	Fixed carbon, and moisture, free 12
I	8.366	8.415	— 49	— .6	8.770	79.1
II	8.351	8.409	— 58	— .7	8.675	78.4
III	7.821	7.763	+ 58	+ .7	8.624	75.3
IV	8.234	8.290	— 56	— .7	8.653	78.0
V	8.292	8.211	+ 81	+ 1.0	8.680	78.1

I. Lump coal, Durham Mine, Walker County.
II. S. T. Carson's property, Walker County. Vein 120 feet below Durham.
III. S. T. Carson's property, Walker County. Vein 180 feet below Durham.
IV. Washed coal, Durham Mine.
V. Unwashed coal, Lookout Coal & Coke Co., Walker County.

The last two columns show that all these coals belong to the same class, the differences not being greater than those that might arise in coal from the

[1]Coal Deposits of Georgia: Georgia Geological Survey Bull. No. 12, 1904, pp. 112-113.

[2]Contained in report by S. W. McCallie, Geological Survey of Georgia, Bull. No. 12, 1904, pp. 116-117.

same mine from difference of sample combined with experimental errors. They fall in the lower part of the semi-bituminous class, whose heating value, according to Prof. Wm. Kent, ranges from 8,666 to 8,888 calores, and whose fixed carbon ranges from 75 to 85 per cent.[1]

WINNING THE RAW MATERIALS

The winning of the raw materials is one of the most important factors to be taken into consideration in the cost of cement manufacture and one which has probably been most neglected. In North Georgia the raw materials can only be economically won by open quarrying. It is most desirable to locate the quarries on the hillside in order to secure a long working face, to facilitate the drainage of the quarry so that wet weather will not interfere with quarrying and to make it possible to convey the raw materials to the mill by means of gravity. It is seldom possible to secure both the limestone and the shale in such an ideal position; however, if the two materials are not in immediate proximity it is most desirable to locate the mill, provided all other conditions are satisfactory, at the source of the liemstone, as about three or four parts of limestone are used to one part of shale.

The quarrying consists first of stripping the overburden, if such occurs, which, in North Georgia, usually consists of residual or transported clays more or less heterogeneous in physical and chemical character, in order to prevent the contamination of this material with the quarry stone. The method of working the quarry depends on the local topographic and geologic conditions. Limestone quarries are usually best worked in one or more benches. After the drilling and blasting of the rock from place, the more massive rock is sledged or reblasted and then loaded either by hand or steam shovel into carts or small cars and taken to the stone house. When a quarry is worked to a considerable depth below water level or some distance from the mill the raw material may be lifted from the quarry and conveyed to the mill by means of an aerial tram. In the quarrying of shale where it is physically homogeneous over a sufficient thickness, steam shovels are far more satisfactory than in the winning of limestone.

[1]Emerson, William H., in Coal Deposits of Georgia: Geol. Survey of Georgia, Bull. No. 12, 1904, pp. 116-117.

Process of Manufacture

Limestone.—The limestone first undergoes a preliminary crushing, which results in a stone of about two inches in diameter. The stone necessary for the day's run passes directly to the rotary driers, while the excess of crushed stone should pass to storage bins having a ten days to two weeks capacity in order to provide for the night's run and to supply the mill in case of any break-down in the stone house. The driers both for limestone and shale, if located close to the kilns, can utilize the waste heat from the kilns and save the additional expense of fuel for drying the raw materials. When the limestone leaves the driers it should be conveyed to storage bins with at least a twenty-four hour capacity, so that the mill will be supplied with stone in case of any delay in the drying. The limestone then passes to the mills for preliminary grinding, from which it is conveyed to a storage bin.

Shale.—The shales first undergo a preliminary crushing and are conveyed, like the limestone, to storage and driers and thence to the mills for preliminary grinding, from which it is conveyed to a storage bin.

Mixture of limestone and shale.—The ground limestone and shale at this point in the process of manufacture are drawn from the storage bins in the proper proportions as determined by the chemist and thoroughly mixed. The mix can be made by alternate drawing of portions of the calcareous and argillaceous materials or by the use of automatic mixing machines. The mix is then conveyed to the pulverizing machines, from which it passes to the kilns where it is burned to incipient vitrification and passes out of the slightly inclined rotary kilns as clinker and is conveyed either to cylindrical coolers or direct to the clinker pile, where it is exposed to the atmosphere and allowed to season and soften. The cool and seasoned clinker is conveyed to the finishing house. The clinker now undergoes a preliminary grinding, the gypsum to retard the set is added and then the ground clinker must be pulverized. After the process of the fine grinding is complete the cement passes to the stock house where it is stored and seasoned and then packed in bags ready for shipment.

Hints in Construction of Plants

1. Each grinding unit should have its storage bin with at least a twenty-four hour capacity.

2. Each kiln should be provided with a storage bin with at least a twenty-four capacity.

3. The limestones of North Georgia available for the manufacture of cement are hard compact semi-crystalline to crystalline in physical character and require a heavy machine for their grinding and pulverizing.

4. Sufficient grinding machinery to provide for an ample capacity should be installed, so that the mills can turn out considerable more material than is ordinarily required of them.

5. In order to acquire the greatest efficiency all machines which operate together in carrying out any one process should have their power derived from the same source.

6. The power should be so subdivided that any machine may be cut out without stopping the operation of other machines.

SLAG OR PUZZOLAN CEMENTS

The raw materials from which the slag or Puzzolan cements is made in this country consist of blast-furnace slag and high-calcium limestone. The analyses of the slag must be constantly made so that the proper cement mixture can be made up either before or after the preliminary grinding. The process after the mixture of the raw materials is precisely like that of Portland cement manufacture.

The specifications for blast-furnace slag are as follows[1]:

Silica (SiO_2)	22 to 30	per cent.
Alumina and iron oxide (Al_2O_3, Fe_2O_3)	11 to 16	" "
Lime (CaO)	49 to 52	" "
Magnesia (MgO)	less than 4	" "
Alkalies (Na_2O, K_2O)	less than 1.5	" "
Loss by ignition	less than 2.5 to 7.5	" "

[1]Mathews and Grasty, Limestones of Maryland, with special reference to their use in the manufacture of lime and cement: Special Publication Maryland Geol. Survey, Vol. VIII, Pt. 3, 1910, p. 325.

OXYCHLORIDE CEMENTS

The raw materials from which these cements are derived consist of magnesite from which the carbon dioxide (CO_2) is driven off and the resulting magnesia is treated with a solution of magnesium chloride ($MgCl_2$) of 25 to 30 degrees Baume. This cement has been used in considerable quantity in the past year for interior work, that is, for walls and flooring. When it is mixed with crushed stone and used for flooring it results in a very hard and durable floor. The cement is quick setting, and attains a very considerable compressive and tensile strength, exceeding that of Portland cement. By the addition of various pigments it can be placed on the market in any color.

HISTORY OF CEMENT DEVELOPMENT IN THE SOUTHERN STATES

Natural cement rock was found in the Southern States in 1829 at Louisville, Ky., and at Shepherdstown, W. Va. In 1836 cement rock was discovered at Cumberland, Md., and in 1837 A. B. McFarlan, a contractor of Washington, D. C., found cement rock at Round Top, Md., on the north bank of the Potomac River. In 1848 the James River cement works were established at Balcony Falls, Va., by H. O. Locher. In 1850 cement rock was found at Cement, Bartow County, Ga., by the Rev. Chas. W. Howard, of Charleston, S. C. A second plant was established at Rossville, Ga., in 1901.

In the early history of the natural cement industry in this country the large production was primarily due to canal construction. About the year 1890 Portland cement, a more complex hydraulic cement began to largely supplant natural cement for use in mammoth construction work where great strength and soundness are required.

The first Portland cement mill established in the South was the Virginia Portland Cement Company, at Fordwick, Va., in 1900. During the following year, the Southern Cement Company, North Birmingham, Ala., began the manufacture of Portland cement from granulated slag and hydrated lime. Three plants were put into operation during 1903: the Buckhorn Portland Cement Company, in West Virginia; the Southern States Portland Cement Company, in Georgia; and the Texas Portland Cement Company, in Texas. In 1904 the only plant in Kentucky was constructed.

The production of Portland cement in the Southern States prior to 1906 was practically negligible. The Standard Portland Cement Company, in Alabama, was completed in the year 1906, and during this year seven mills produced 1,804,643 barrels, constituting 3.9 per cent. of the total output in the United States. During 1907 the Dixie Portland Cement Company of Tennessee and the Dewey Portland Cement Company of Oklahoma were established. In 1907 eight plants of the Southern States produced 1,814,470 barrels, or 3.7 per cent. of the total output. In 1908, the Security Cement and Lime Company in Maryland, and the Oklahoma Portland Cement Company in Oklahoma, began operations, and eleven plants of the Southern States produced 2,204,840 barrels, or 4.3 per cent. of the total output. During 1909, the Southern States Portland Cement Company in Texas was constructed, and in this year twelve plants produced 3,811,498 barrels, constituting 6.1 per cent. of the total output. The following year, the Atlantic and Gulf Portland Cement Company in Alabama, the Southwestern Cement Company in Texas, and the Norfolk Portland Cement Corporation in Virginia, all began operations, so that in 1910 fifteen plants produced 5,717,959 barrels, or 7.9 per cent. of the total output. The plants of the Tidewater Portland Cement Company in Maryland, the Clinchfield Portland Cement Corporation in Tennessee, the Piedmont Portland Cement Company in Georgia, and the Choctaw Portland Cement Company in Oklahoma, were all completed during 1911. The total output for this year is not now available.

The present capacity of the Southern mills, together with the contemplated increase in capacity during 1912, will give the Southern mills a daily capacity of 44,880 barrels, or an annual capacity of more than 16,000,000 barrels.

The Portland cement plants of the Southern States at present are as follows: Maryland, two plants; Virginia, two; West Virginia, one; Kentucky, one; Tennessee, two; Georgia, two; Alabama, three; Oklahoma, three; and Texas, four. Missouri has four plants. The description of these several plants in the different states are given below.

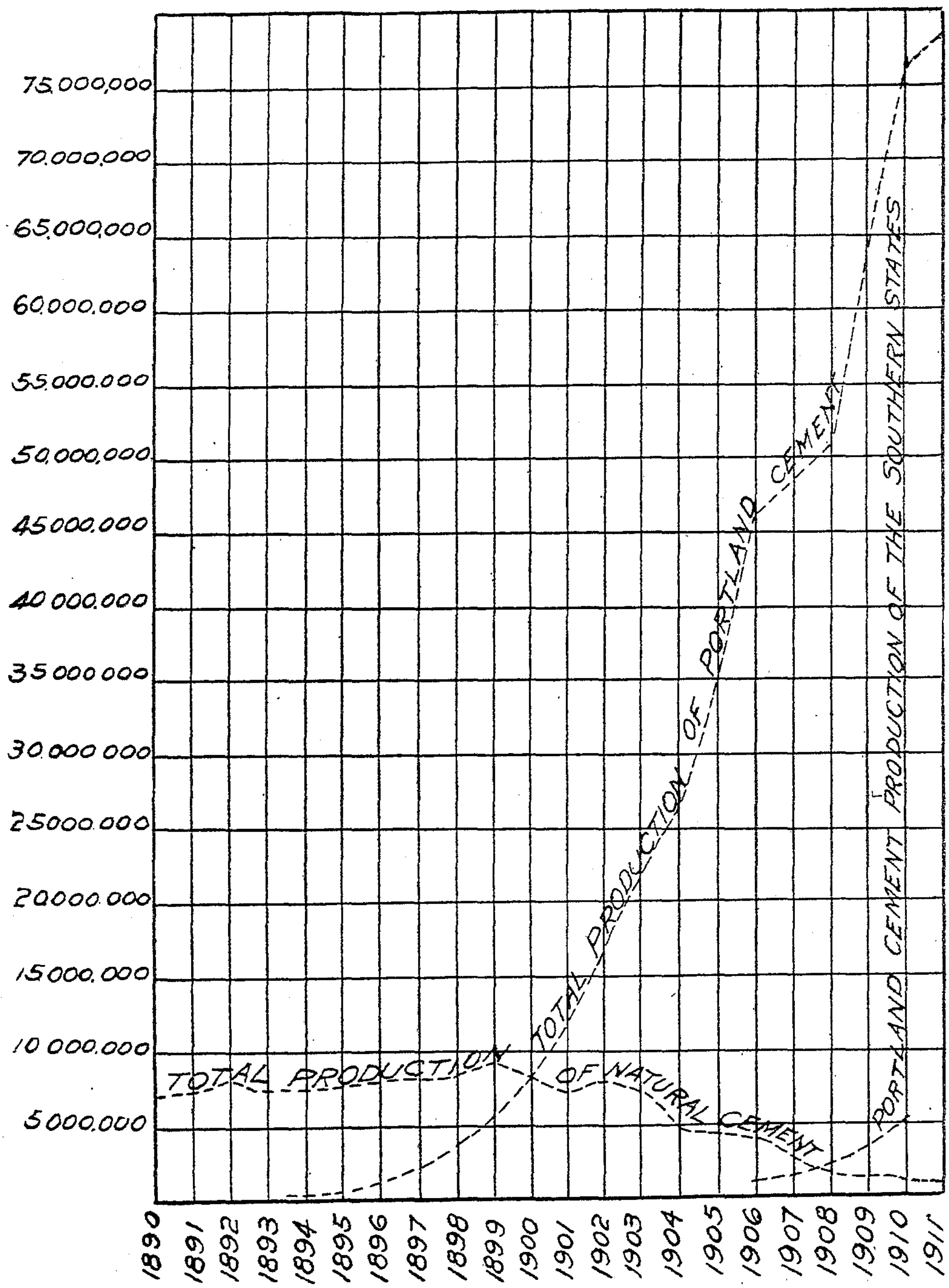

FIG. 1.—TABLE SHOWING PRODUCTION OF NATURAL AND PORTLAND CEMENTS IN THE UNITED STATES, AND OF PORTLAND CEMENT IN THE SOUTHERN STATES, SINCE 1890.

MARYLAND

Security Cement and Lime Company[1].—This plant is located at Security, Md. The plant was completed and put into operation with its present daily capacity of 800 barrels during the summer of 1908. It was constructed by the Maryland Portland Cement Company, which company combined in the fall of 1909 with the Berkley Lime Company of West Virginia to form the present corporation. This new company is increasing the daily capacity of the plant to 2,400 barrels. The brand is "Security."

The raw materials consist of the limestones of the Conococheague formation of Cambrian age and the Martinsburg shale of Ordovician age.

Analyses of the Raw Materials and Cement, Security, Maryland

Constituents	Limestone			Shale			Cement
Silica (SiO_2)	7.06	6.04	5.62	62.60	63.91	59.74	21.72
Alumina (Al_2O_3)	1.08	1.96	1.21	21.25	18.73	22.63	7.66
Ferric oxide (Fe_2O_3)	1.01	.62	.81	5.23	8.11	3.16	2.50
Lime (CaO)	49.14	48.88	49.78	.36	none	.73	62.91
Magnesia (MgO)	1.70	1.74	1.58	.94	1.83	2.43	2.30
Sulphur trioxide (SO_3)	----	----	----	----	----	----	1.48
Ignition	40.02	39.30	40.96	-----	7.41	7.73	-----
	100.01	98.54	99.96	90.38	99.99	96.42	98.57

Tidewater Portland Cement Company.—The plant of this company is located at Union Bridge, Md., within 45 miles of tidewater. It was completed and put into operation during the fall of 1911. It consists of a mill with a daily capacity of 2,400 barrels of gray Portland and 600 barrels of white Portland cement. The lime plant has a daily capacity of 60 tons of common lime and hydrated lime.

The limestones used by this plant occur in the Loudon formation of Lower Cambrian age, while the argillaceous material is a slate which is an altered volcanic rock correlated with the Catacton schist. This volcanic slate shows a composition rather low in silica, so that

[1]Mathews, Edward, and Grasty, J. S., The Limestones of Maryland, with special reference to their use in the manufacture of Lime and Cement: Md. Geol. Survey, Special Pub., Vol. VIII, pt. 3, 1910.

the ratio of silica to alumina falls below 2 to 1. This deficiency of silica may be obviated by the utilization of the Newark shales of Triassic age which occur within a quarter of a mile of the plant[1].

Analyses[2] of Limestones, Union Bridge, Maryland

Silica (SiO_2)	4.46	1.40	6.40	1.73	0.28	1.26	1.08
Alumina (Al_2O_3) } Ferric oxide (Fe_2O_3)	.52	.24	.62	.56	.24	.36	.20
Lime (CaO)	51.94	53.75	51.04	53.45	54.45	54.35	54.89
Magnesia (MgO)	1.10	1.06	.65	1.08	1.34	.64	.46
Ignition	42.03	43.41	40.84	43.19	44.27	43.41	43.63
	100.05	99.86	99.55	100.00	100.58	100.02	100.26
Calcium carbonate ($CaCO_3$)	92.75	95.98	91.14	95.45	97.23	97.05	98.01

Analyses of Shales and Clinker, Union Bridge, Maryland

Constituents	Shale			Gray clinker	White clinker
Silica (SiO_2)	58.00	52.74	54.54	19.94	22.12
Alumina (Al_2O_3)	22.28	23.44	24.24	7.57	7.56
Ferric oxide (Fe_2O_3)	8.40	11.30	9.80	3.45	.28
Lime (CaO)	.42	.20	.85	65.58	64.10
Magnesia (MgO)	2.06	2.33	1.78	1.69	1.03
Sulphur trioxide (SO_3)	-----	-----	-----	.26	.21
Ignition	-----	-----	-----	.62	.74
	91.16	90.01	91.21	99.11	96.04

VIRGINIA

Virginia Portland Cement Company[3].—The plant of the Virginia Portland Cement Company is situated at Fordwick, Va. It was established in June, 1900. The plant has a daily capacity of 3,000 barrels. The brand is "Old Dominion."

The raw materials consist of the Lewistown limetsone and the Romney shale, both of Devonian age.

[1]Information concerning the geology furnished by Dr. J. S. Grasty, Asst. State Geologist of Virginia.

[2]Mathews, E. B., and Grasty, J. S., The Limestones of Maryland, with special reference to their use in the manufacture of lime and cement: Md. Geol. Survey, Vol. VIII, Pt. 3, 1910.

[3]Data supplied by Virginia Portland Cement Company, R. J. Hawn, Superintendent.

Analyses of Raw Materials and Cement, Fordwick, Virginia

Constituents	Limestone C-3395	Shale C-3325	Cement
Silica (SiO_2)	4.40	56.92	21.60
Alumina (Al_2O_3)	.94	17.83	6.85
Ferric oxide (Fe_2O_3)		4.79	2.53
Pyrites (FeS_2)	-----	1.22	-----
Lime (CaO)	51.20	4.30	62.18
Magnesia (MgO)	2.93	3.62	2.90
Water, alkalies, organic matter, etc	40.53	7.80	3.94
	100.00	96.48	100.00
Calcium carbonate ($CaCO_3$)	91.44	7.82	-----

Norfolk Portland Cement Corporation[1].—The plant of the Norfolk Portland Cement Corporation is located on the south branch of the Elizabeth River opposite the United States Navy Yard near Norfolk. The plant is a subsidiary company of the American Cement Company, Philadelphia, Penn., and was built during the year 1910. The brand is "Giant."

The raw materials consist of marls and clays. The marls occur in the Yorktown formation of Miocene age, while the clays are of Quaternary age. The raw materials are transported to the plant by barges from Pigeon Creek, a tributary of James River, 22 miles distant. The clay bank is situated just above Smithfield, while the marl beds occur on the opposite side of the creek between Smithfield and Battery Park.

Analyses of Raw Materials and Cement, Norfolk, Virginia

Constituents	Marl	Clay	Cement
Silica (SiO_2)	12.38	65.06	24.36
Alumina (Al_2O_3)	3.31	19.21	4.98
Ferric oxide (Fe_2O_3)	3.81	6.59	5.42
Lime (CaO)	44.00	1.06	62.81
Magnesia (MgO)	.57	.82	.64
Sulphur trioxide (SO_3)	-----	-----	-----
Ignition	35.30	7.14	.51
	99.37	99.88	98.72

[1]Data supplied by Dr. J. S. Grasty, Asst. State Geologist of Virginia.

MARBLE BLUFF, NEAR WHITESTONE, ON THE LOUISVILLE AND NASHVILLE RAILROAD, GILMER COUNTY, GEORGIA

WEST VIRGINIA

Buckhorn Portland Cement Company.—The mill of the Buckhorn Portland Cement Company is located at Manheim, W. Va. Operations were begun in the year 1903 with an average daily capacity of 800 barrels. The Alpha Portland Cement Company secured this mill early in the year 1909 and has since increased the daily capacity of the mill to 1,500 barrels. The brand is "Alpha."

The raw materials consist of the Greenbriar limestone of Lower Carboniferous (Mississippian) age and shales of the same age. Quarternary clays are found along the river flats; however, these clays are not at present used in the mix.

Analyses[1] of Raw Materials and Cement, Manheim, West Virginia

Constituents	Limestone	Shale	Clay	Cement
Silica (SiO_2)	12.84	54.22	60.42	22.82
Alumina (Al_2O_3) } Ferric oxide (Fe_2O_3)	4.34	29.36	19.30	9.14
Lime (CaO)	44.60	.61	2.10	61.24
Magnesia (MgO)	1.21	.97	2.00	1.80
Sulphur trioxide (SO_3)	-----	-----	-----	1.56
Ignition	37.01	-----	-----	-----
	100.00	85.16	83.82	96.56

KENTUCKY

Kosmos Portland Cement Company.—The mill of the Kosmos Portland Cement Company is located at Kosmosdale, Ky. The plant was established in the year 1904, and has an average daily capacity of 1,500 barrels. The company is now engaged in enlarging the plant to an average daily capacity of 3,000 barrels.

The raw materials[2] consist of the Genevieve limestone of Lower Carboniferous (Mississippian) age and residual clays derived from the upper Waverly formation of the same age.

[1]Analyses furnished by G. S. Brown, 2nd Vice-President, Alpha Portland Cement Company.

[2]Data supplied by Prof. Arthur M. Miller, Lexington, Ky.

Analyses[1] of Raw Materials and Cement, Kosmosdale, Kentucky

Constituents	Limestone	Clay	Raw mix	Cement
Silica (SiO_2)	1.50	67.30	15.00	22.45
Alumina (Al_2O_3) Ferric oxide (Fe_2O_3)	.85	23.60	5.20	8.55
Lime (CaO)	53.50	.60	42.50	63.40
Magnesia (MgO)	1.00	.80	1.30	2.00
Sulphur trioxide (SO_3)	-----	1.20[2]	1.15[2]	1.50
Alkalies (Na_2O,K_2O)	-----	-----	-----	.60
Ignition	43.15	6.50	34.85	1.50
	100.00	100.00	100.00	100.00

TENNESSEE

Dixie Portland Cement Company.—The plant of the Dixie Portland Cement Company is located at Richard City, Tenn. The plant began operations November 1, 1907. The brand is "Royal."

The ultimate daily capacity of the plant is between 6,000 and 7,000 barrels, while the average daily output at the present time is about 4,000 barrels. The raw materials consist of the Bangor limestones and Pennington shales, both of lower Carboniferous (Mississippian) age.

Analyses[3] of Raw Materials, Raw Mix and Cement, Richard City, Tennessee

Constituents	Limestone	Blue shale	Red shale	Raw mix	Cement
Silica (SiO_2)	2.70	52.78	67.02	13.78	22.00
Alumina (Al_2O_3) Ferric oxide (Fe_2O_3)	.80	28.16	20.46	5.70	9.92
Lime (CaO)	52.30	2.56	1.41	42.18	63.16
Magnesia (MgO)	1.16	3.32	2.36	1.99	2.97
Sulphur trioxide (SO_3)	-----	-----	-----	-----	1.41
Ignition	42.75	11.38	8.85	35.69	1.26
	99.71	98.20	100.10	99.34	100.72

Clinchfield Portland Cement Corporation.—The plant of the Clinchfield Portland Cement Corporation is located at Kingsport, Tenn. The

[1]Analyses supplied by Mr. C. M. Dugan, Jr., Gen. Mgr., Kosmos Portland Cement Co.

[2]By difference.

[3]Analyses furnished by Mr. J. H. Guenther, Chief Chemist, Dixie Portland Cement Company.

mill was completed and put into operation June 1, 1911, with an output of 1,200 barrels daily. This output will shortly be increased to 3,000 barrels per day. The brand is "Clinchfield."

The raw materials[1] consist of limestone and shale. The limestone is obtained from the Chickamauga formation and the shales from the Athens formation, both of which are of Ordovician age.

Analyses[2] of Raw Materials, Mix, and Cement, Kingsport, Tennessee

Constituents	Limestone	Shale	Uncalcined mixture	Cement
Silica (SiO_2)	0.58	63.39	14.40	21.82
Alumina (Al_2O_3) Ferric oxide (Fe_2O_3)	.86	27.08	6.98	10.70
Lime (CaO)	54.87	.26	42.56	63.31
Magnesia (MgO)	.81	1.87	.92	1.21
Sulphur trioxide (SO_3)	none	none	none	1.50
Ignition	43.04	6.20	35.08	.66
	100.16	98.80	99.84	99.20

GEORGIA

Southern States Portland Cement Company.—The plant of the Southern States Portland Cement Company is located about 1½ miles directly north of Rockmart, Polk County, Ga. The company was organized by H. F. Vandeventer in 1903. The average daily capacity of the mill is 1,200 barrels. The brand is "Southern States."

The materials used in the manufacture of cement are obtained from the Chickamauga limestone and the Rockmart shale and slate. Both formations are of Ordovician age.

Analyses[3] of Raw Materials and Cement, Rockmart, Georgia

Constituents	Limestone	Shale	Cement
Silica (SiO_2)	1.62	60.01	21.21
Alumina (Al_2O_3) Ferric oxide (Fe_2O_3)	1.25	21.88 3.85	11.24
Lime (CaO)	53.22	2.32	61.82
Magnesia (MgO)	1.30	1.36	2.73
Sulphur trioxide (SO_3)	-----	-----	1.66
Ignition	42.37	6.53	1.21
	99.76	95.95	99.87

[1]Data furnished by Prof. C. H. Gordon, Tenn. Geol. Survey.

[2]Analyses furnished by Mr. S. Henry Harrison, Gen'l Mgr., Clinchfield Portland Cement Corporation.

[3]Analyses furnished by Mr. J. L. Mack, Chemist, Southern States Portland Cement Company.

Piedmont Portland Cement Company.—The plant of the Piedmont Portland Cement Company is located at Portland, Polk County, Ga. The company began operations in the spring of 1911. The daily capacity of the mill is 500 barrels. The brand is "Piedmont."

The materials used in the manufacture of cement are obtained from the Chickamauga limestone and the Rockmart shale and slate, both of Ordovician age.

Analyses[1] of Raw Materials and Cement, Portland, Georgia

Constituents	Limestone	Shale	Cement
Silica (SiO_2)	2.06	59.26	23.92
Alumina (Al_2O_3)	1.71	21.38	9.94
Ferric oxide (Fe_2O_3)	.33	7.02	-----
Lime (CaO)	51.71	.42	60.93
Magnesia (MgO)	1.82	2.30	3.72
Sulphur trioxide (SO_3)	-----	-----	1.31
Ignition	42.06	6.19	1.07
	99.69	96.57	100.89

ALABAMA

Southern Cement Company.—The plant of the Southern Cement Company is located at North Birmingham, Ala., and was established in the year 1901.

The raw materials[2] consist of granulated furnace slag and hydrated lime. This company makes a Portland cement, "Alabama" brand, and also what they term a semi-Portland, "Magnolia" brand.

Analyses of the Slag and Portland Cement, North Birmingham, Alabama

Constituents	Slag	Cement
Silica (SiO_2)	32.40	30.00
Alumina (Al_2O_3)	14.60	13.20
Ferric oxide (Fe_2O_3)	-----	.75
Lime (CaO)	50.37	52.00
Magnesia (MgO)	1.77	1.25
Sulphur trioxide (SO_3)	.86	1.00
Ignition	-----	1.80
	100.00	100.00

[1]Analyses furnished by Mr. W. S. Davis, Supt., Piedmont Portland Cement Company.

[2]Data supplied by Mr. Harold R. Sanson, Gen. Mgr., Southern Cement Co.

Standard Portland Cement Company.—The plant of the Standard Portland Cement Company, established in 1906, is located at Leeds, Ala. The daily capacity of the plant is 1,250 barrels. The brand is "Standard."

The raw materials[1] consist of the Trenton limestone of Ordovician age and the lower Carboniferous (Mississippian) shales. Free sandstone is also added.

Analyses[2] of Raw Materials and Cement, Leeds, Alabama

Constituents	Limestone	Shale	Sandstone	Cement
Silica (SiO_2)	1.82	56.81	94.02	23.56
Alumina (Al_2O_3)	1.10	21.94	3.08	6.52
Ferric Oxide (Fe_2O_3)		8.13	.40	2.60
Lime (CaO)	53.15	1.76	1.66	63.16
Magnesia (MgO)	1.24	2.22	----------	1.64
Sulphur Trioxide SO_3)	----------	----------	----------	1.71
Ignition	42.89	7.68	1.02	--------
	100.20	98.54	100.18	99.19

Atlantic and Gulf Portland Cement Company.—The plant of the Atlantic and Gulf Portland Cement Company is located at Ragland,

Analyses[3] of Raw Materials and Cement, Ragland, Alabama

Constituents	Limestone		Shale		Mix		Cement	
Silica (SiO_2)	1.60	3.30	63.80	60.24	13.70	14.69	22.07	22.30
Alumina (Al_2O_3)	.78	1.22	19.03	21.10	6.32	6.36	6.48	7.11
Ferric oxide (Fe_2O_3)			7.97	8.38			2.64	2.99
Lime (CaO)	52.38	51.23	none	.20	42.29	41.00	62.89	62.82
Magnesia (MgO)	1.85	1.78	1.37	1.88	1.86	1.79	2.77	2.57
Sulphur trioxide (SO_3)	------	------	------	------	------	------	1.36	1.46
Ignition	42.84	42.64	6.86	7.64	35.00	35.64	1.05	.92
	99.45	100.17	99.03	99.44	99.17	99.98	100.26	100.17

[1]Data furnished by Dr. W. F. Prouty, Asst. State Geologist of Alabama.

[2]Data furnished by Mr. L. E. Mallery, Chemist of the Standard Portland Cement Company.

[3]Analyses furnished by Mr. Clarence N. Wiley, Gen. Mgr., Atlantic and Gulf Portland Cement Company. Made by Pittsburgh Testing Lab., Birmingham, Ala.

Ala. The company began producing cement June 6, 1910. The brand is "Coosa."

The average daily capacity of the plant is 2,400 barrels. The capacity of the plant will be increased to 3,000 barrels during the coming year.

The raw materials consist of the Chickamauga limestones of Ordovician age and the shales of the upper Carboniferous (Pennsylvanian).

Alabama Portland Cement Company[1].—The plant of the Alabama Portland Cement Company is located near Demopolis, Ala. This plant was not in operation during 1911. The raw materials consist of the Selma chalk of Cretaceous age and the residual clays.

Mobile Portland Cement and Coal Company[2].—The Mobile Portland Cement and Coal Company planned to establish a plant at old St. Stephens Bluff on the Tombigbee River, and to utilize the St. Stephens limestone. The plans have never materialized, probably due to the fact that several locks, which are in the process of construction between Demopolis and the coal fields, are not yet completed, and the plant could not be regularly supplied under the present conditions with fuel.

OKLAHOMA

Dewey Portland Cement Company[3].—The plant of the Dewey Portland Cement Company is located at the town of Dewey, in Washington County, four miles north of Bartletsville, on spur tracks running from the Atchison, Topeka & Sante Fe, and the Missouri, Kansas & Texas railroads. The main office is at Kansas City, Mo. The plant began operations in 1907 with a capacity of 3,000 barrels per day. The brand is "Dewey."

The raw materials consist of the Dewey limestone of middle Pennsylvanian age and shales of the same age, which lie immediately above the Dewey limestone.

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[1]Data furnished by Dr. Wm. F. Prouty, Asst. State Geologist, Alabama Geological Survey.

[2]Data furnished by Dr. Wm. F. Prouty, Asst State Geologist, Alabama Ceological Survey.

[3]Data furnished by Prof. Chas. N. Gould, Director, Oklahoma Geological Survey.

Analyses[1] of Raw Materials and Cement, Dewey, Oklahoma

Constituents	Argillaceous Limestone	High Calicum Limestone	Shale	Raw mix	Cement
Silica (SiO_2)	11.92	1.40	83.04	14.96	22.98
Alumina (Al_2O_3)	6.45	.92	7.29	3.60	5.88
Ferric oxide (Fe_2O_3)			2.79	1.80	2.79
Lime (CaO)	44.24	54.65	1.90	42.58	65.33
Magnesia (MgO)	1.23	tr.	tr.	.98	1.70
Sulphur trioxide (SO_3)					1.
Ignition	36.29	43.29	4.76	36.16	
	100.13	100.26	99.78	100.08	100.01

Oklahoma Portland Cement Company[2].—The plant of the Oklahoma Portland Cement Company is located one mile southwest of the town of Ada, Okla. The plant began operations during 1907. The mill has a capacity of 3,000 barrels per day. The brand is "O. K."

The raw materials consist of limestone from the top of the Viola formation of Ordovician age and the Sylvan shale of Silurian age.

Analyses of Raw Materials and Cement, Ada, Oklahoma

Constituents	Limestone	Shale	Cement
Silica (SiO_2)	0.42	42.30	22.04
Alumina (Al_2O_3)	.71	12.56	7.10
Ferric oxide (Fe_2O_3)	.10	5.92	3.12
Lime (CaO)	55.08	12.86	62.00
Magnesia (MgO)	.28	5.50	2.40
Sulphur trioxide (SO_3)			
Ignition	43.11	18.11	2.06
	99.70	97.25	98.72

Choctaw Portland Cement Works[3].—The plant of the Choctaw Portland Cement Works is located 1½ miles south of Hartshorn,

[1]Analyses by R. P. Chamberlain, Chief Chemist, Dewey Portland Cement Co.

[2]Data furnished by Prof. Chas. N. Gould, Director, Oklahoma Geological Survey.

[3]Data furnished by Prof. Chas. N. Gould, Director, Oklahoma Geological Survey.

Okla., on a spur track of the Chicago, Rock Island & Pacific Railroad. The Choctaw Portland Cement Works was organized in July, 1909, and the plant began operations in the fall of 1911 with a capacity of 1,500 barrels. The brand is "Elephant."

The calcareous material consists of the Wapanucka limestone of lower Pennsylvanian age. The shale is obtained from a bed just beneath the limestone and is of the same age.

Analyses[1] of Raw Materials and Cement, Hartshorn, Oklahoma

Constituents	Limestone	Shale	Cement
Silica (SiO_2)	1.10	55.50	22.85
Alumina (Al_2O_3)	.60	19.25	10.31
Ferric oxide (Fe_2O_3)	.10	7.65	
Lime (CaO)	54.70	5.60	63.28
Magnesia (MgO)	1.10	.60	1.57
Alkalies (Na_2O, K_2O)	--------	.96	--------
Sulphur trioxide (SO_3)	tr.	tr.	1.47
Ignition	42.00	10.00	--------
	99.60	100.36	99.48

TEXAS

Alamo Cement Company.—The works of the Alamo Cement Company are located at San Antonio, Texas. The plant was established in 1879 and incorporated in 1880.

The raw materials[2] consist of the Eagle Ford argillaceous limestones and shale of the Black Prairie series of upper Cretaceous age. The materials are mixed in the desired proportion.

Analysis[3] of Cement, San Antonio, Texas

Lime (CaO)	61.82
Alumina (Al_2O_3)	13.60
Ferric oxide (Fe_2O_3)	
Lime (CaO)	61.82
Magnesia (MgO)	.58
Sulphur trioxide (SO_3)	.82
Ignition	.....
	99.82

[1]Analyses of limestone and shale by the Kansas City Testing Laboratory, and the analysis of the cement by the Engineering Dept. of Cornell University.

[2]Data furnished by Dr. Wm. B. Phillips, Bureau of Economic Geology, University of Texas.

[3]Data supplied by Mr. Charles Baldus, Alamo Cement Company.

Texas Portland Cement Company.—The plant of the Texas Portland Cement Company is located at Dallas, Texas. The original Texas Portland Cement Company, of which the present company is the successor, was established in 1903 and a mill was located 4½ miles west of Dallas. In 1907 the old plant was abandoned and a new modern mill was built about 200 yards east of the old mill. The plant has a daily capacity of about 3,000 barrels. The brand is "Lone Star."

The raw materials[1], consisting of limestone and shale, are obtained from the Eagle Ford strata of the Austin Chalk, Gulf series of upper Cretaceous age.

Analyses[2] of Raw Materials and Cement, Dallas, Texas

Constituents	Limestone	Shale	Cement
Silica (SiO_2)	8.98	54.80	20.72
Alumina (Al_2O_3)	4.66	22.80	8.15
Ferric oxide (Fe_2O_3)	2.31	5.70	3.60
Lime (CaO)	46.20	3.20	63.18
Magnesia (MgO)	.56	1.25	.75
Sulphur trioxide (SO_3)	----------	.50	1.63
Ignition	36.14	11.66	1.80
	98.85	99.91	99.83

Southwestern States Portland Cement Company.—The plant of the Southwestern States Portland Cement Company is located at Eagle Ford, Texas. Operations were begun July 4, 1909. The brand is "Trinity." The average daily capacity of the plant is from 2,500 to 3,000 barrels.

The raw materials[3] consist of limestones and shales of the Eagle Ford formation of upper Cretaceous age.

[1]Data furnished by Dr. Wm. B. Phillips, Bureau of Economic Geology, University of Texas.

[2]Analyses furnished by Mr. L. L. Griffity, Gen. Supt., Texas Portland Cement Company.

[3]Data furnished by Dr. Wm. B. Phillips, Bureau of Economic Geology, University of Texas.

Analyses[1] of the Raw Materials and Cement, Eagle Ford, Texas

Constituents	Limestone	Shale	Cement
Silica (SiO_2)	6.82	59.87	20.80
Alumina (Al_2O_3)	3.03	17.70	7.44
Ferric oxide (Fe_2O_3)	1.45	5.50	.40
Lime (CaO)	48.40	2.26	64.12
Magnesia (MgO)	1.20	1.15	.95
Sulphur trioxide (SO_3)	----------	--------	1.51
Ignition	38.80	11.80	--------
	99.70	98.28	95.22

Southwestern Portland Cement Company[2].—The plant of the Southwestern Portland Cement Company is located at El Paso, Texas. The company began operations in February, 1910, and began shipment March, 1910. The brand is "El Toro." The average daily capacity of the plant is 1,200 barrels.

The raw materials are taken from the Comanche series of Cretaceous age.

Analyses of Raw Materials and Cement, El Paso, Texas

Constituents	Calceraous materials		Argillaceous materials			Cement		
Silica (SiO_2)	5.01	8.94	22.28	24.35	17.66	23.39	23.14	23.40
Alumina (Al_2O_3) } Ferric oxide (Fe_2O_3)	2.33	3.98	8.68	8.44	6.85	8.67	8.40	{ 5.47 -----
Lime (CaO)	50.47	48.05	37.23	36.78	39.59	63.99	63.18	64.20
Magnesia (MgO)	.99	1.11	.92	1.60	1.16	2.07	2.06	1.83
Sulphur trioxide (SO_3)	------	------	------	.89	------	1.70	1.67	1.37
Ignition	41.20	38.56	30.79	28.00	33.14	.87	.29	.40
	100.00	100.64	99.90	100.06	98.40	100.69	98.74	96.67

[1]Analyses furnished by Mr. M. M. Ludlow, Chemist, Southwestern States Portland Cement Company.

[2]Data furnished by Mr. O. J. Binford, Secretary, Southwestern Portland Cement Company.

PHYSIOGRAPHY, STRUCTURE AND GEOLOGY OF NORTH GEORGIA

PHYSIOGRAPHY

North Georgia is divided into four physiographic provinces known as the Piedmont Plateau, the Appalachian Mountains, the the Appalachian Valley, and the Cumberland Plateau.

PIEDMONT PLATEAU

This plateau lies between the Coastal Plain on the southeast and the Appalachian Mountains on the northwest. The southeastern boundary is known as the Fall Line, which is an irregular line extending from Augusta through Milledgeville and Macon to Columbus. The western boundary is not so well defined as the eastern boundary, but follows a sinuous line extending in a general southwest direction along the eastern base of the Blue Ridge from the South Carolina-Georgia line near Toccoa to the vicinity south of Cartersville, Bartow county. The plateau is characterized by an undulating plain which slopes gently from its western border, where it attains an altitude of about 1,200 feet, to the southeast where the elevation along the Fall Line is from 300 to 500 feet.

APPALACHIAN MOUNTAINS

These mountains are bounded on the southeast by the Piedmont Plateau and on the west by the great Appalachian Valley. They consist of an eastern range of mountains generally known as the Blue Ridge and a western series known as the Unaka Range, comprising the Cohutta Mountains in Georgia. The Blue Ridge and the Unaka are separated by a series of mountains and high valleys.

APPALACHIAN VALLEY

This great valley lies between the highlands of the Appalachian Mountains on the east and the Cumberland Plateau on the west. It is made up of a series of ridges and minor valleys which run in

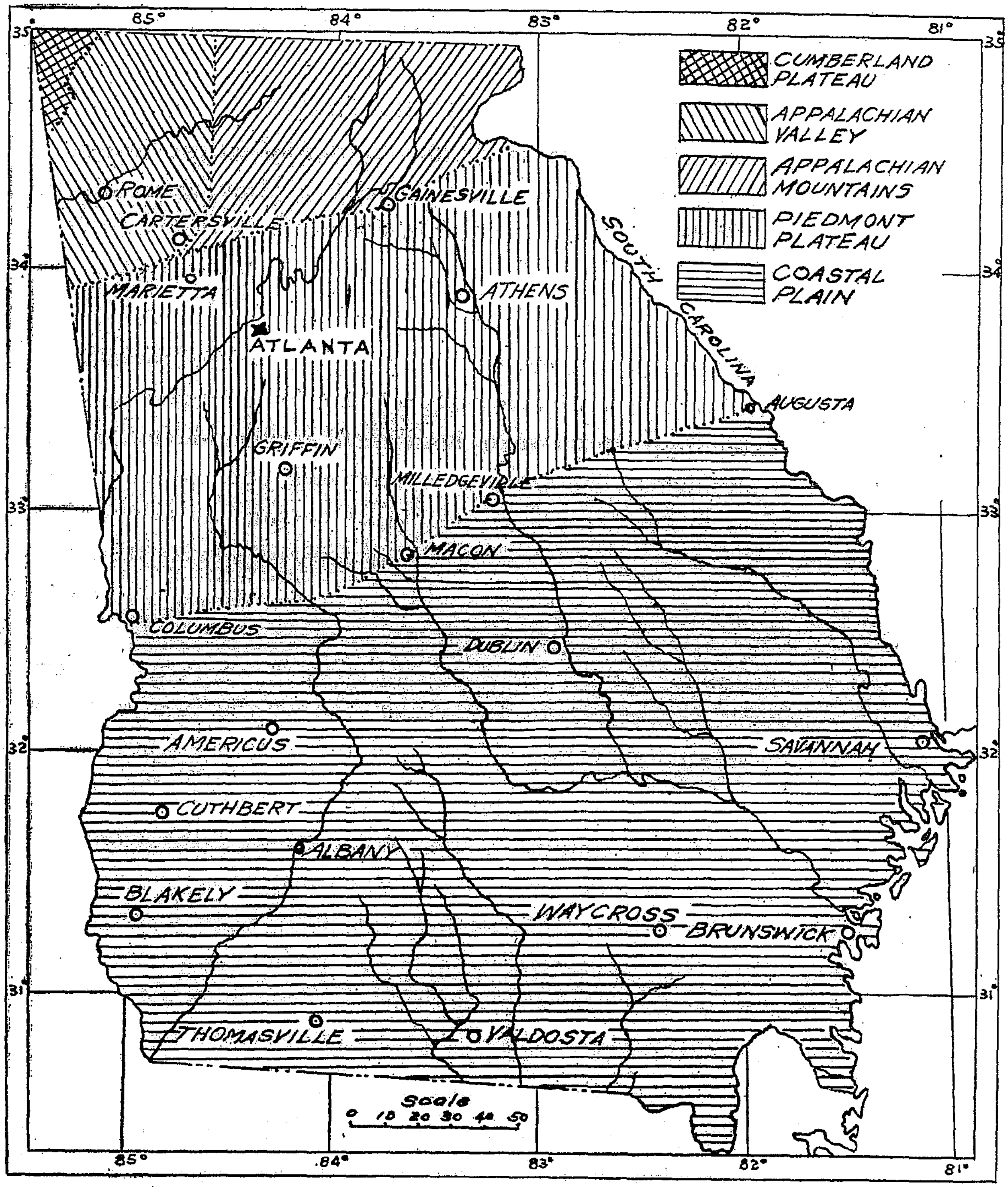

FIG. 2.—MAP SHOWING THE PHYSIOGRAPHIC SUBDIVISIONS OF GEORGIA

an approximately parallel direction. Three types of ridges are found in the area. The Indian mountain type, which extends from Alabama into Georgia, is made up of conglomerate and quartzite. The resistant character of these materials cause them to withstand erosion to a greater extent than the other types, so that they are characterized by a greater altitude. The second type, consists of such ridges as Taylor and Gaylor, and Chattooga and Dirtseller mountains, which extend in a general parallel direction with their crests almost perfectly horizontal and more even than the Indian mountain type. A third type consists of a large number of low elevations rising sometimes several hundred feet above the valley level.

CUMBERLAND PLATEAU

The Cumberland Plateau forms only a comparatively narrow area in the extreme northwest portion of the State. The belt is characterized by abrupt escarpments and flat top table lands. The easternmost of the narrow plateaus is Lookout Mountain, which terminates in a high abrupt point at Chattanooga. Sand Mountain is the southward continuation of Walden Ridge and constitutes the western portion of the Cumberland Plateau area in Georgia. It extends to the southwest into Alabama and to the northeast into Tennessee.

STRUCTURE

The physiographic provinces which have been described above are all characterized by distinct types of structure, so that they are structural as well as physiographic subdivisions.

PIEDMONT PLATEAU

The structure of the Piedmont Plateau is extremely complicated. It contains great areas of holo-crystalline igneous rocks and also holo-crystalline metamorphic rocks of sedimentary origin, all usually much folded and contorted.

APPALACHIAN MOUNTAINS

The structure of the Appalachian Mountains is similar to that which characterizes the great Appalachian Valley. The rocks are intimately folded and faulted, the general trend of the folds being northeast and southwest, which corresponds to the general direction of the faults. The force which produced the folding and faulting acted in a direction at right angles to the folds and came from the southeast as is indicated by the overturned folds to the northwest and the prevailing steep dips to the southeast. Regional metamorphism is a characteristic of the Appalachian Mountain belt and has been due in many cases to intrusions of igneous rocks. The more intense metamorphism to which these rocks have been subjected has developed minerals characteristic of metamorphic rocks and a cleavage or tendency to split has developed across the strata.

APPALACHIAN VALLEY

The rocks of the Appalachian Valley usually dip at high angles. They have been compressed into folds having a general northeast and southwest trend. These rocks have been faulted in many places, the displacements running approximately parallel to one another and usually parallel to the folds. The main force which caused the faulting and folding came from the southeast, as is indicated by the overturned folds to the northwest. The fault planes, as well as the predominating dip to the southeast, also indicate the direction of this force. In the eastern portion of the great Appalachian Valley, where the materials have been subjected to intense pressure, the finer-grained rocks, like the shales, have been largely recrystallized, and in the rearrangement of the constituents during recrystallization they have assumed distinct cleavage.

CUMBERLAND PLATEAU

The rocks of the Cumberland Plateau occupy shallow synclines and have been disturbed but little from their original almost horizontal position. North Georgia has been subjected many times to horizontal compressions, elevations, and the degrading effects of sub-areal erosion.

GEOLOGY

The four physiographic provinces which comprise North Georgia all differ in the character of their rocks. The Piedmont Plateau contains the oldest rocks in the State and as we proceed westward crossing the Appalachian Mountains, the Appalachian Valley, and the Cumberland Plateau, we traverse strata that become successively younger in geologic age.

PIEDMONT PLATEAU

This plateau is made up largely of holo-crystalline and semi-crystalline rocks of both igneous and sedimentary origin and rocks so completely metamorphosed that all traces of their former origin have been obliterated.

The holo-crystalline igneous rocks consist primarily of granites, gneisses and schists cut by a series of younger basic eruptives made up largely of diabases and diorites. Belts of basic ferro-magnesian silicates are found traversing the State in a general northeast and southwest direction. They have been classed as eruptive rocks by King.[1]

The rocks of undoubted sedimentary origin consist of conglomerates, quartzites, slates and limestones, while many of the schists associated with these sedimentary rocks are thought to be of the same origin. Dynamic and metamorphic agencies have been so great and have extended over such a long period of time in the Piedmont Plateau that the diorites and many of the granites have taken on a gneissoid structure; shales have changed into slates, which in turn have been metamorphosed into phyllites; sandstones have been consolidated into quartzites; and both igneous and sedimentary rocks have been changed into schists.

The rocks have a prevailing dip to the southeast throughout the plateau and the dip varies usually from thirty to ninety degrees. The general direction of the strike is N. 20° to 30° E.

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[1]King, Francis P., A Preliminary Report on the Corundum Deposits of Georgia: Bull. Geol. Survey of Ga. No. 2, 1894, p. 71.

Table of Geological Formations of the Appalachian Valley and Cumberland Plateau Areas of Georgia

Era or System	Period or Group	Formation	Thickness feet	General character
Carboniferous	Pennsylvanian	Walden sandstone	930	Sandstone and shale
		Lookout formation	500	Massive sandstone at base succeeded by sandstones and shales with heavy conglomerate and sandstone at top.
		Unconformity		
	Mississipian	Pennington shale	780+	Carbonaceous shales with sandstone in upper portion
		Unconformity		
		Bangor limestone (Probably time equivalents)	900	Heavy-bedded, high-calcium limestone with some magnesian limestones.
		Floyd formation (Probably time equivalents)	1,500+	Carbonaceous shales with some heavy-bedded, dark-blue limestones.
		Fort Payne chert	200	Chert and cherty limestone.
		Unconformity		
Devonian	Upper	Chattanooga black shale	20	Black shale.
	Middle (absent)	Unconformity		
	Lower	Frog mountain sandstone and Armuchee chert	40	Sandstone and chert.
Silurian	Upper (absent)	Unconformity		
	Middle Niagrian	Rockwood formation	1,600	Olive-green shales with many thin beds of brown and green sandstones.
	Lower (absent)	Unconformity		
Ordovician	Upper	(Western basin) Chickamauga formation; (Eastern basin) Rockmart shales and slates	2,500+	Brown and olive-green shales with sandstones and limestone conglomerate in upper portion.
	Middle	(Eastern basin) -Unconformity- Chickamauga limestone	200	Dark-blue and gray limestones.
		Unconformity		
	Lower	Knox dolomite	5,000	Largely crystalline, heavy-bedded, gray dolomite with much chert.
Cambrian	Upper Cambrian or Sarratogan		2,000	Yellow and brown argillaceous shales with some blue limestone containing argillaceous intercalations and veins of secondary calcite.
	Middle Cambrian or Acadian	Connasauga shales and limestone		
	Lower Cambrian or Georgian	Rome formation	3,500	Variegated shales and sandstones.
		Apison shale	1,000	Vari-colored argillaceous shales.
		Beaver limestone	1,100+	Heavy-bedded, gray magnesian limestone.
		Weisner quartzite	2,500+	Quartzite.

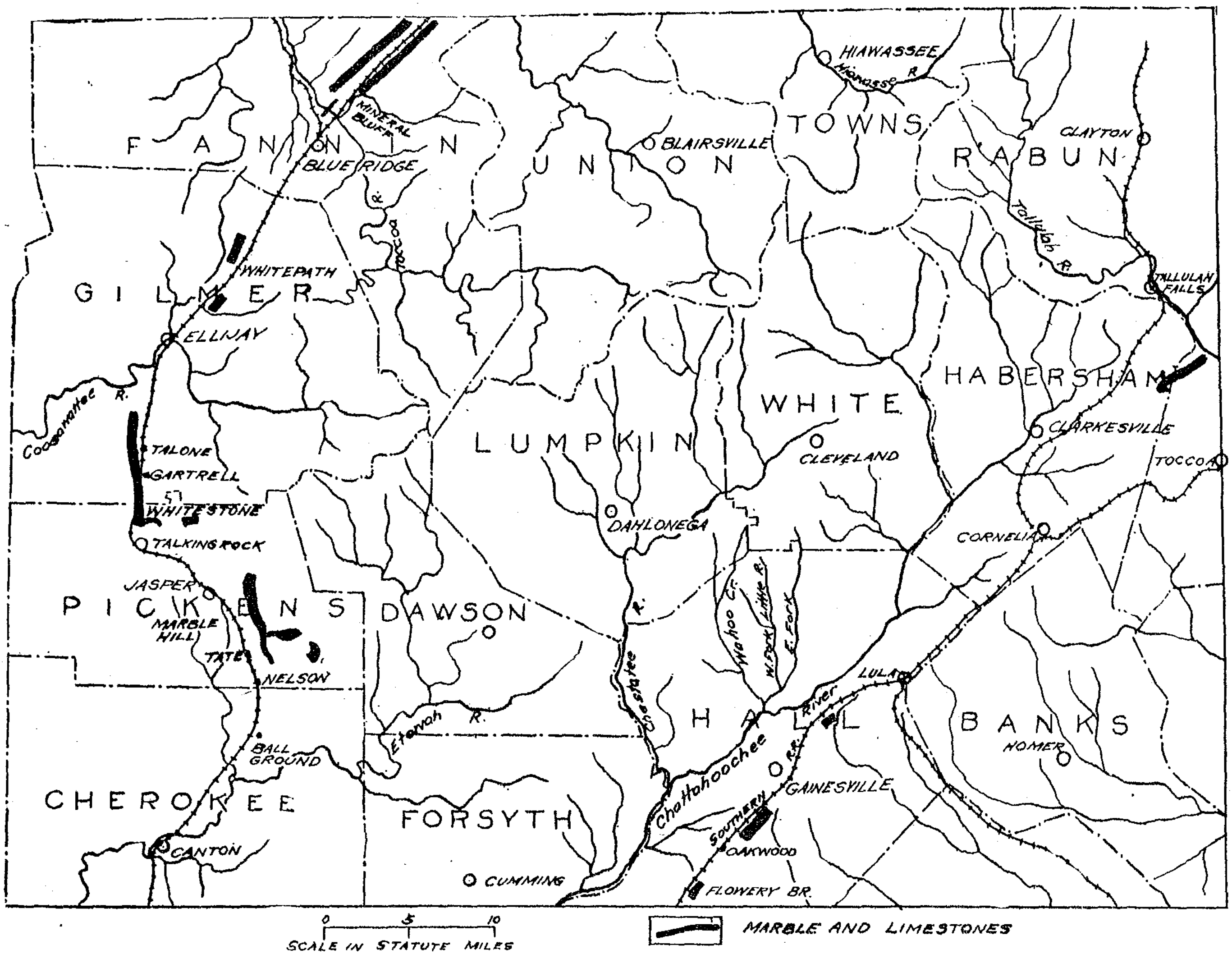

FIG. 3.—MAP SHOWING THE AREAL DISTRIBUTION OF MARBLES AND LIMESTONES IN THE PIEDMONT PLATEAU AND APPALACHIAN MOUNTAIN AREAS OF GEORGIA

APPALACHIAN MOUNTAINS

These mountains consist of crystalline rocks of igneous origin, such as granite and diorite, associated with crystalline schists which are in part derived from igneous and in part from sedimentary rocks, together with undoubted sedimentary rocks, such as quartzites, conglomerates, slates, marbles, and limestones, all of which have been more or less altered by heat and pressure. The igneous rocks are more prominent in the east and southeastern portion of the belt, while the metamorphosed clastics prevail to the west.

MURPHY MARBLE

The Murphy marble of Cambrian age is the only formation in the Appalachian Mountains of Georgia containing calcareous materials of commercial importance. This formation is an extension of the Murphy marbles of North Carolina, so named by Keith.[1]

Areal distribution.—These calcareous rocks enter the extreme northeast corner of Fannin County in two almost parallel lines of outcrops separated by a fault. They continue to the southwest, traversing Gilmer, Pickens, and Cherokee counties, sometimes occurring along a single belt and again occupying two belts. The exposures are often widely separated, due to the fact that these rocks are in places concealed by the overlying formations.

Lithologic character.—The calcareous rocks differ both in physical and chemical character. The physical character of the Murphy marble is largely due to differences in degree of metamorphism, resulting from pressure, folding, faulting, etc. The three pronounced types of stone are: high-calcium, holo-crystalline and coarsely crystalline marbles, fine crystalline magnesian marbles; and fine-grained, largely crystalline, blue limestones. The commercial marbles are all high-calcium and holo-crystalline. The impurities originally contained in these marbles have crystallized out in the form of graphite, hematite, mica, tremolite, and a few other minerals. The magnesian marbles are all finely crystalline. Trem-

[1]Keith, Arthur, Nantahala folio (No. 143), Geol. Atlas U. S., U. S. Geol. Survey, 1907.

olite and talc have developed, especially along planes which appear to be identical with planes of stratification; and other impurities, as mica, pyrite, etc., are also contained in the magnesian stone. Slipping has taken place, as shown by striations on the silicates. The blue limestones are partly crystalline and few secondary minerals have been developed in them.

Paleontology.—Prof. S. W. McCallie,[1] says:

Some years ago when making a study of the marbles of the State, the writer discovered, in the marbles of Turniptown Creek valley, what appeared to be imperfectly preserved fossils. The material was submitted to Prof. Charles D. Walcott, Director of the U. S. Geological Survey, who, upon examination, stated that the specimens appeared to contain organic remains; but what they were he was unable to state, further than that they suggested sections of gastropod shells.

APPALACHIAN VALLEY AND CUMBERLAND PLATEAU

CAMBRIAN

The Cambrian rocks of Georgia consist of sandstones, quartzites, conglomerates, shales, slates, dolomites, limestones, and marbles. To the east of what Hayes terms the Cartersville fault, the Cambrian rocks have suffered far greater metamorphism, due to more intense diastraphic movements than those rocks of the same age lying to the west of this fault in the great Appalachian Valley.

The lower Cambrian quartzites and conglomerates of the Appalachian Valley appear to be of continental origin. The transgression of the sea in early Cambrian time was gradual and the argillaceous beds contained in the Beaver limestone indicate comparatively shallow water conditions. The upper part of the lower Cambrian, consisting of the sandstones and shales of the Rome formation, contain ripple marks which are evidence of their shallow water origin.

During Connasauga or middle Cambrian time in Georgia, the interior sea transgressed over a wide area, and while shallow

[1]McCallie, S. W., Marbles of Georgia, Bull. Geol. Survey of Ga. No. 1, 2nd edition, 1907, p. 34.

waters continued to exist they were deeper than the waters of lower Cambrian time. Limestones and argillaceous muds were deposited.

The gradual submergence, which took place in the southern Appalachian region in the middle Cambrian, continued and became more pronounced in the upper Cambrian during which time the marine waters of the southern Appalachian sea[1] reached their greatest depth.

The upper Cambrian, consisting of the lower 600-700 feet of the Knox dolomite, lies apparently conformable upon the Connasauga formation.

The three divisions of the Cambrian are characterized by three genera of trilobites: the lower Cambrian, or Georgian, by *Olonellus;* the middle Cambrian, or Arcadian, by *Paradoxides,* in the Atlantic basin, and by *Oleonides* in the Appalachian region south of the Champlain Valley; and the upper Cambrian, or Saratogan, by *Dikelocephalus.* Schuchert[1] says: "In the lower Cambrian, or Georgian, from Labrador to Alabama the life represented is essentially that of the *Olonellus thomsoni* fauna."

WEISNER QUARTZITE

The Weisner quartzite is of lower Cambrian age. The stratigraphic relation of this formation to adjacent formations of known lower Cambrian age has furnished the evidence for placing it among the lower Cambrian rocks.

Areal distribution.—The Weisner quartzite is found in two important areas in Georgia. It forms Indian Mountain, the northeast portion of which extends from Alabama into the northwestern portion of Polk County, Ga. On account of the resistant nature of the quartzite, which largely composes this formation, it always gives rise to marked topographic features, as in the case of Indian Mountain, which reaches an altitude of more than 1,950 feet.

[1]Schuchert, Chas., Discussion of Continental Seas: Bull. Geol. Soc. of Amer., Vol. 20, 1910, pp. 447-464.

[1]Bull. Geol. Soc. of Amer., Vol. 20, 1910, p. 517.

AN EXPOSURE OF WEISNER QUARTZITE ALONG THE WESTERN & ATLANTIC RAILROAD, AT THE IRON BRIDGE OVER THE ETOWAH RIVER, 1 MILE EAST OF CARTERSVILLE, GEORGIA, SHOWING THE CRUSHING AND FOLDING OF THE QUARTZITE

Just east of Cartersville, the Weisner quartzite extends in a general north and south direction for about fifteen miles and in places reaches a maximum width of three miles.

Lithologic character.—Hayes[1] says:

> It consists chiefly of fine-grained vitreous quartzite, although it also contains some beds of fine conglomerate and probably considerable beds of siliceous shales. The latter, however, are usually concealed by the abundant "debris" from the quartzite beds, which tend to break up into angular fragments when exposed to atmospheric conditions.
>
> The thickness of this formation is probably 2,000 to 3,000 feet and may be considerably more; but it cannot be determined because of the intense folding which its beds have undergone and the absence of satisfactory exposures.[2]

The Weisner formation occurs in the form of a massive lense varying greatly in thickness over a small area. The coarser elements of the formation occur in a series of lenses interbedded with the finer grained rocks and vary considerably in thickness. The beds of conglomerate often contain numerous angular feldspar fragments showing that the material composing the conglomerate was derived in part from granite. The angular character of the fragments shows that they were not far removed from their original source. The above enumerated facts, together with the general absence of fossils, are evidence against the marine origin of the formation and point to delta deposits as suggested by Hayes.

Paleontology.—Prof. S. W. McCallie found in this formation at a point near Cartersville what appeared to be the remains of brachiopods, corals, etc.; however, none have been found sufficiently preserved to be determined.

BEAVER LIMESTONE

The Beaver limestone lies stratigraphically immediately above the Weisner quartzite and is of lower Cambrian age. Hayes[3] estimates the thickness of this formation at not less than 800 to 1,200 feet.

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[1]Hayes, C. W., Geological Relations of the Iron Ores in the Cartersville District, Georgia: Am. Ins. Min. Eng., Vol. XXX, 1901, p. 404.

[2]Ibid, p. 410.

[3]Op. cit., p. 406.

Areal distribution.—The Beaver limestone occupies a narrow belt to the west of the Weisner quartzite in the Cartersville district and extends from a point about three miles south of Cartersville to the northeast for about 18 miles. In addition to this belt it underlies a broad level valley extending southward from Grassdale to the vicinity of Ladds Mountain.

Another area extends along the southeast side of Indian Mountain from the Georgia-Alabama line to the vicinity of Oredell.

Lithologic character.—Wherever the formation is present in Georgia it is largely concealed and valley-forming. The few exposures that occur show it to be a semi-crystalline, gray, dolomitic limestone containing in places considerable chert, while again it is somewhat argillaceous in character.

The formation is usually overlain by a mantle of deep red residual clay containing chert derived from the dolomitic limestone and quartzite fragments derived from the Weisner quartzite.

Paleontology.—No fossils have been found in this formation to the writer's knowledge.

APISON SHALE

The Apison shale succeeds the Beaver limestone in the geologic column and is overlain by the Rome formation. Hayes[1] estimates the thickness of this shale in Georgia at not less than 1,000 feet. On account of the rather intense folding and faulting it is impossible to measure its exact thickness.

Areal distribution.—The Apison shale enters Georgia from Tennessee at a point about two miles east of White Oak Mountain and covers a lenticular-like belt extending in a southwest direction to a point two miles east of Ringgold. Another small lenticular shaped area is found in the southwestern portion of Whitfield County.

Lithologic character.—The formation consists of argillaceous shales with alternating bands of red, purple, green and yellow.

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[1]Hayes, C. W., Ringgold folio (No. 2), Geol. Atlas U. S., U. S. Geol. Survey, 1894.

Paleontology.—As far as known no fossils have been found in this formation in Georgia.

ROME FORMATION

The Rome sandstones and shales occupy a position immediately above the Beaver limestone in the Cartersville district, while they lie above the Apison shale wherever these shales are found. Hayes[1] estimates the thickness of this formation at from 3,000 to 4,000 feet.

Areal distribution.—The Rome sandstones and shales occupy three areas in the Appalachian Valley region of Georgia.

The most northwestern area occupied by the Rome formation extends in a southwest direction from the Georgia-Tennessee line at a point about 2 miles east of White Oak Mountain to a point about 1½ miles southwest of Villanow. A wedge-shaped area of Knox dolomite separates the Rome formation into two narrow belts in the northern part of this area

The Rome formation is most typically exposed in the central area which extends in a general northeast direction from a point just north of the Floyd-Polk county line at the Georgia-Alabama line through Rome and into the Dalton area to the northeast.

The eastern area occupies a belt intimately associated with the Connasauga formation to the north of Cartersville.

Lithologic character.—The Rome formation of the northwestern area consists of interbedded sandstones and shales in the lower portion, while the upper portion consists of argillaceous and siliceous shales. The sandstones are reddish, brown and purple in color, while the shales are brown, reddish and olive green.

The formation of the central belt consists of interstratified thin beds of fine-grained sandstones and siliceous shales, and contains thin-bedded red sandstones at the base of the formation, while at the top there is a heavy bed of light-gray sandstone.

In the area to the northeast of Rome, the formation is largely

[1]Hayes, C. W., Ringgold and Rome folios (Nos. 2 and 78), Geol. Atlas U. S., U. S. Geol. Survey, 1894 and 1902.

made up of shales. The alternate bands of vari-colored sand-stones and shales and the usual brilliant coloring of these bands is a striking peculiarity of this formation. The sandstones interbedded with the shales cause this formation to be more resistant to erosion than the overlying Connasauga, and as a consequence give rise to a series of hills both to the northeast and southwest of Rome which are characteristic topographic features of the formation.

Paleontology.—Lingula (?) were found in a glauconitic sandstone by Prof. S. W. McCallie in the Rome sandstone at a point about two and one-half miles east of Ringgold.

CONNASAUGA SHALES AND LIMESTONES

The Connasauga formation of middle Cambrian age varies in thickness between 1,500 and 2,000 feet,[1] and consists essentially of shales with interstratified limestones which in places reach a thickness of 150 feet.

Areal distribution.—The Connasauga formation extends across the State in the western portion of the great Appalachian Valley, usually in narrow areas, while in the Coosa Valley southwest of Rome and in the eastern portion of the Appalachian Valley it occupies broad areas.

The most western belt of the Connasauga enters the State just west of Graysville, forming Peavine and Chattooga valleys and extends in a southwest direction across the State into Alabama.

A narrow belt extends in a southwest direction from a point on Cane Creek north of Trion forming the valley traversed by the Central of Georgia Railway and extending into Alabama. Irregular lense-like areas also occur in the vicinity of the Alabama line.

In the Coosa Valley southwest of Rome the Connasauga forms a wide valley known as the "Flatwoods." This formation extends both to the northeast and southwest of Rome. It occupies a comparatively broad valley to the northeast of Rome extending into

[1]Hayes, C. W., Ringgold folio (No. 2), Geol. Atlas U. S., U. S. Geol. Survey, 1894.

A VIEW SHOWING OUTCROP OF BLACK MARBLE AT THE QUARRY OF THE AMERICAN BLACK MARBLE COMPANY, WHITFIELD COUNTY, GEORGIA the valley east of Dalton. The formation extends to the southwest of Rome into Alabama and forms irregular, long, narrow areas along the Georgia-Alabama line.

A very narrow belt extends from the northwest corner of the Catoosa-Whitfield county line to the southwest through Tunnel Hill into East Armuchee Valley, reaching a point about four miles southwest of Villanow.

In the Cartersville and Dalton areas the formation occupies broad valleys and is intimately associated with the sandstones and shales of the Rome formation.

Lithologic character.—The shales of the Connasauga formation are always fine-grained extremely argillaceous rocks and olive green to yellowish-green in color. At the base of the formation thin bedded limestones interstratified with shales are usually present, succeeded by olive green to yellowish-green shales with limestones of considerable thickness at the top of the series.

The limestones vary in physical and chemical character over wide limits. Some of the limestones have an oölitic-like structure. The oölitic limestones and those of the dark blue color are high in calcium. The gray limestones usually contain intercalated clayey impurities which are conspicuous on the weathered surface of the rock. In places the gray rock is crystalline and resembles somewhat the Knox dolomite, but it never contains the chert so characteristic of the upper Knox. The limestones are nearly always characterized by secondary calcite veins. In the crushing to which these rocks were subjected by earth movements, the shales readily adjusted themselves by folding, while the limestones, being more rigid, were fractured. The openings thus produced were subsequently filled with calcite deposited by percolating waters containing lime in solution, derived from the same formation. In the Coosa Valley flat and rounded siliceous concretions are found which sometimes contain trilobites. When the limestones reach their maximum thickness in this formation they form low ridges, while the general argillaceous and calcareous character of the formation causes it to be valley-forming.

Paleontology.—The Connasauga formation contains the most abundant fauna of the Cambrian rocks in Georgia. Spencer[1] says:

These shales of the Coosa Valley contain fossils which from a point three miles southwest of Rome, C. D. Walcott has determined as belonging to the genus Oleonides, and consequently belong to the middle Cambrian series. * * * * The shale ridges (which contain some sandstone) to the east of the basin below Rome apparently belong to a position beneath the shales to the west as well as to the east of them, owing to the Oostanaula fault upon their western side.

The shale ridges to which Spencer refers as containing some sandstones are undoubtedly the sandstones and shales of the Rome formation. The fact that the genus *Oleonides* was found in the shales above the sandstones and in the Coosa Valley leaves little doubt that the *Oleonides* came from the Cannasauga shales.

Spences again says:[2]

In the northern suburb of Rome, from arenaceous shales and clays above the sandstones, fossils of the genus Bathyuriscus were found, and from the sandstones Annelid remains. * * * On the eastern side of and above the sandstone ridges, seven miles south of Rome, a bed of limestone intercalated with shales, contains Bathyuriscus and Ptychoparia and species of Orthis all belonging to middle Cambrian fauna.

The sandstones to which Spencer again refers are the sandstones of the Rome formation and from his description there is some doubt as to whether *Bathyuriscus* was found in the upper shales of the Rome formation or in the Cannasauga; however, the fauna which he describes as coming from a bed of limestone intercalated with shales is undoubtedly Connasauga. *Oleonides curticei* (Walcott) occurs in the siliceous concretions in the Connasauga formation.

The limestones of the Connasauga are in places made up largely of the remains of trilobites and a small fossil (concretion-like), which is thought to be *Girvanella,* occurs in the Connasauga limestone near the base of Cedar Ridge east of Dalton.

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[1]Spencer, J. W., The Paleozoic Group of Georgia: Bull. Geol. Survey of Ga., 1893, p. 38.

[2]Ibid, p. 40.

CAMBRO-ORDOVICIAN

KNOX DOLOMITE

The Knox dolomite of Cambro-Ordovician age lies immediately above the shales and limestone of the Connasauga formation. It attains a thickness of from 4,000 to 5,000 feet and consists of heavy bedded and massive partially crystalline dolomite.

Areal distribution.—The formation forms a broad area occupying Missionary Ridge and extending from the Georgia-Tennessee line dividing into narrower belts as it approaches the Alabama line.

The Knox dolomite forms narrow irregular areas between Taylor Ridge on the west and the series of mountains on the east known as Johns, Horn, and Chattoogata mountains.

East and southeast of Rome the Knox dolomite forms a great valley area with no well defined ridges, while long narrow ridges are characteristic of the formation in the western portion of the Appalachian Valley region. The formation extends to the southwest to the vicinity of the Alabama line and covers a broad area extending to the northeast. It turns to the north in the vicinity of Cartersville and narrows out in the northern portion of Gordon County.

In the northeastern portion of the great Appalachian Valley, the Knox dolomite extends from the Georgia-Tennessee line in four somewhat broad areas to the south, becoming wedge-shaped at their southern extremities.

Lithologic character.—The formation is characterized by low narrow ridges and broad valleys, depending on the local structure and the physical character of the beds exposed. The lower 500 to 700 feet of this formation in Alabama, Georgia, and Tennessee is known to be of upper Cambrian age and differs from the overlying portion of the Knox in the general absence of chert.

In Alabama the lower 500-600 feet of the Knox dolomite has been separated from the upper portion of the formation by Butts[1] and called

[1]Bull. 400, U. S. Geol. Survey, 1910, p. 14.

the Ketona dolomite, on account of its great economic importance and its difference in lithologic character from the upper part of the formation. In Tennessee and Georgia the lower 500 to 700 feet are practically free from chert and might here also be termed the Ketona dolomite; however, it could not be separated from the overlying Knox dolomite areally. No attempt has been made in Georgia to recognize any of the subdivisions of this formation. According to Ulrich, the upper limit of the Cambrian is drawn at the top of the main cherty mass of the Knox dolomite as exhibited in "Copper ridge." The base of the upper Cambrian or Ozarkic of Ulrich begins "with the lower non-cherty member of the Knox."

The lower portion of the formation is characterized by heavy and massive beds of gray largely crystalline dolomite without chert, while the upper beds are characterized by a considerable abundance of chert in the form of layers and nodules. In the eastern portion of the area the dolomite contains some sandy beds in the upper part of the formation.

Paleontology.—In the lower portion of the Knox dolomite fossils have been found which show that it is of upper Cambrian age, while in the upper portion the fauna shows it to be of lower Ordovician age.

In the railroad cut about one mile south of Cleveland, Tenn., the lower portion of the Knox dolomite is exposed and carries *Ptychoparia* and other Cambrian fossils[1].

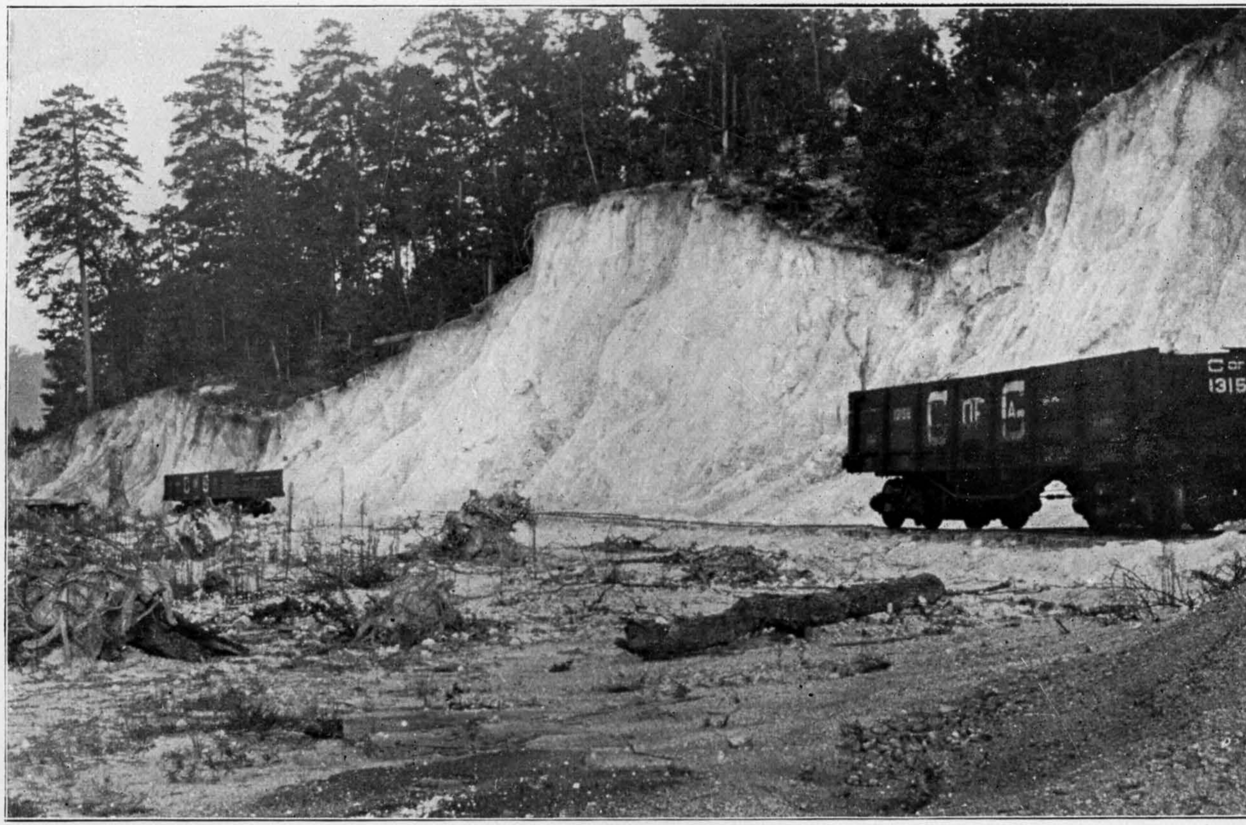
ORDOVICIAN

The rocks of the Ordovician in Georgia consist of dolomites, limestones, and shales.

At the beginning of Ordovician time in Georgia the great marine transgression occurring in upper Cambrian time continued and the Knox dolomite which was deposited represents the lower Ordovician in part.

At the close of the lower Ordovician or Canadic (Ulrich) period a general regressive movement of the sea covering the Appalachian

[1]Spencer, J. W., Paleozoic Group of Georgia: Geol. Survey of Georgia, 1893, p. 41.



RESIDUAL CHERT AND CLAY RESULTING FROM THE WEATHERING OF THE KNOX DOLOMITE, IN A CUT ON THE CENTRAL OF GEORGIA RAILWAY, NEAR SUMMERVILLE, CHATTOOGA COUNTY, GEORGIA

Valley region took place. The elevation of the continent and a hiatus of great extent is shown by the extensive unconformity between the Knox dolomite and the Chickamauga formation. Ulrich and Schuchert, in their "Paleozoic Seas and Barriers" have advanced the idea that during Ordovician time the Appalachian Valley was divided longitudinally into several narrow basins which were more or less separated from one another, thus accounting for the observed differences in sedimentation and life characterizing the several areas.

The lower Ordovician or Canadic (Ulrich) period followed the upper Cambrian or Ozarkic (Ulrich) period in the Southern Appalachians with a gradual change in fauna. Little is known of the fauna of the upper Knox dolomite in the Southern Appalachian Valley.

During middle Ordovician time the southern type of fauna was in general the Stones River type. The Atlantic fauna mingled in middle and later Chazy times, as shown by the occurrence of *Maclurea magma,* a well known species of the Atlantic Mid-Chazy period.

The upper Ordovician is represented in part in the upper portion of the Chickamauga formation.

CHICKAMAUGA FORMATION

The Chickamauga formation, representing both middle and, in part, upper Ordovician time in Georgia, consists of all the rocks lying between the Knox dolomite below and the Rockwood formation above. This formation consists of two distinct types of rocks differing both in lithologic and faunal character. These sediments were deposited in basins separated by a barrier of Knox dolomite, and the basins extended much farther than the limits of Georgia; however, they may be termed in Georgia the western and the eastern basins. The rocks of the Chickamauga formation to the west of the Oostanaula River were laid down in the western basin and several long narrow areas in the northeastern portion of the Appalachian Valley region of Georgia also belong to this basin. The rocks of the western basin consist of interbedded limestones and shales and in places consist essentially of limestones.

The eastern basin was narrow and probably extended some distance to the southwest into Alabama. It covered the area in the vicinity and to the south of Cedartown, and in the Rockmart region it covered the area now occupied by the Chickamauga limestone and the Rockmart shale, and in all probability extended some distance to the east.

The formation reaches a thickness of 1,800 feet in the western basin, and in the eastern basin the limestones reach a thickness of probably 200 feet, while the shales may be 2,500 to 3,000 feet[1] in thickness.

Areal distribution.—The Chickamauga formation forms long narrow areas when the dip of the rocks is inclined at a high angle, while it forms long broad valleys when the crests of gently dipping anticlines are exposed.

The most western belt occupies the crest of a broad anticline and extends from the vicinity of Wildwood in a southwest direction along the valley of Lookout Creek to within two miles of the Alabama line.

A small "V"-shaped area extends from the Tennessee line in the vicinity of Chattanooga to a point about four miles to the south.

A long narrow area extends from a point about two miles south of the Tennessee line into the southern extremity of McLamore Cove. It occupies both the east and west sides of the valley of this cove and extends down the valley of Chickamauga Creek to the north into Tennessee. The formation follows around the northeast end of Pigeon Mountain and occupies a narrow area in the valley to the east of Pigeon and Lookout mountains.

Another area occupies the southeast and southwest sides of Dirtseller Mountain and extends to the north where it narrows to a point about three miles northwest of Trion. It occupies the western flanks of Taylor and Gaylor ridges, Simms, Heath, Turnip, John, Horn, and Chattoogata mountains and some intermediate areas.

In the northeastern portion of the Appalachian Valley in Georgia three long narrow areas of the Chickamauga formation are found. The first area underlies the valley at Dalton and extends several miles

[1]Hayes, C. W., Rome folio (No. 78), Geol. Atlas U. S., U. S. Geol. Survey, 1902.

to the north and south of the town. The second area enters the State from Tennessee at a point about one mile east of Red Ore and extends about eight miles to the southwest. The third area enters the State in the extreme northeastern portion of the Appalachian Valley and extends to the south to the vicinity of Loughbridge.

The Chickamauga formation in the eastern basin has been divided by Hayes[1] into the Chickamauga limestones and the Rockmart shales. Limestones occupy the valley in the vicinity of Cedartown and extend several miles to the south. The main belt of limestones and shales extends from the vicinity of Hightower Mill in Polk County to the northeast and occupy the broad valley to the north of Rockmart, becoming narrower to the northeast and extending to the vicinity of Stilesboro.

Lithologic character.—The Chickamauga formation shows such wide differences in its lithologic character, both in a direction parallel to the strike and across the same in the western basin that it is found necessary to describe the outcrops in some detail.

The formation in Lookout Valley consists of a hard, flaggy, blue limestone, carrying an abundant fauna. The eastern base of Lookout and Pigeon mountains and in the Chickamauga Valley the formation consists largely of thin-bedded blue limestones with some beds of earthy, purple, and dove-colored limestone. The earthy beds are more numerous towards the east and the formation increases in thickness in that direction. In the area extending from the Georgia-Alabama line, both on the east and west sides of Dirtseller Mountain and extending in a northeast direction to a point several miles northwest of Summerville, the formation consists of mottled earthy limestones and interbedded variegated shales. The base of the formation in the southwestern portion of this belt contains a conglomerate consisting of cherty fragments which were derived from the Knox dolomite. The fragments are somewhat water worn and are imbedded in a calcareous mud.

The western side of Taylor Ridge, Simms Ridge, Gaylor Ridge,

[1] Op cit.

Turnip, Horsleg, Chattoogata, Horn, and John mountains, the formation is largely of argillaceous character consisting of interbedded earthy limestones and variegated shales.

The rocks of the Chickamauga formation to the east of the Oostanaula River outcrop in the vicinity of Cedartown and Rockmart. The Chickamauga formation in the eastern basin consists of two distinct members. The lower portion has been termed the Chickamauga limestone by Hayes and the upper portion the Rockmart shales and slates.

CHICKAMAUGA LIMESTONE

The Chickamauga limestone is separated from the Knox dolomite below and from the Rockmart shale and slate above by unconformities. It consists of from 100 to 200 feet of thin and heavy bedded, fine grained, high-calcium limestone interbedded with gray to grayish-blue magnesium limestone. The dark blue high-calcium beds predominate in the lower portion of the formation while the upper beds contain a greater number of magnesian beds.

ROCKMART SHALES AND SLATES

The shales of the Rockmart formation are of great thickness. The formation consists largely of dark blue to black shales and slates, weathering often to olive green and yellow. The lower portion of the formation is remarkably uniform in its lithologic character, while the upper portion is more variable, containing highly ferruginous sandstones, cherty limestones, and conglomerates.

Paleontology.—The rocks of the Chickamauga formation of the western basin contain an abundant fauna. Below are given some of the more abundant fossils observed by the writer.

Corals	Peleycepods
Bryozoa	Gastropods
Brachiopods	Cephalopods
Camerotoechia sp.	Gonioceras anceps (Hall)
Plectambonites sericeous (Sowerby)	Trilobites
Rafinesquina alternata (Conrad)	Ostracods

The Chickamauga limestones of the eastern basin are practically barren of fossils. The Rockmart shales have never been carefully searched for fossils.

Silurian

At the close of the Ordovician time there was almost a complete emergence of the Appalachian Valley area which was followed by the Niagara transgression. The deposits of the Silurian in Georgia are mainly clastics consisting of shales and sandstones with an occasional bed of interstratified limestone. These materials were derived from a rejuvinated Appalachian land area to the east. The Rockwood formation, which is delimited by the Chickamauga formation below and the Chattanooga black shales above, is separated from both of these formations by profound unconformaties. This formation constitutes all that remains of the Silurian deposits of Georgia. The eastern sandy phase of the Rockwood formation represents near shore deposits of shallow water origin which gradually merge to the west into deeper water deposits, consisting of shales and some interstratified limestones. As far east as Taylor Ridge the iron ore contains marine fossils in abundance. The deposits in the western part of the Appalachian Valley area were deposited in deeper waters than those to the east. The waters were all comparatively shallow during lower Silurian time in Georgia.

ROCKWOOD FORMATION

The Rockwood formation in Georgia attains a thickness of 600 to 1,600 feet and represents the Clinton of New York and possibly more. The formation consists of sandstones and shales with some conglomerates in the eastern area and some interstratified limestones in the western area. It contains the most important commercial iron ores of the Southern Appalachians.

Areal distribution.—The Rockwood formation extends across the western portion of the Appalachian Valley in long narrow belts. The formation is characterized by differences both in its character of topography and lithology to the west of Taylor Ridge and to the east of and including Taylor Ridge. The region to the west of Taylor

Ridge has been termed the western area and the region including Taylor Ridge and the mountains to the east have been designated the eastern area.

The western area contains five distinct belts. The first belt extends from the Tennessee line in the valley of Lookout Creek in a southwest direction occupying the ridges on both sides of the valley, coalescing and terminating at a point about one mile southwest of the Alabama line.

The second belt occupies the valley of Johnsons Crook, and forms ridges on both sides of the valley extending to the southwest into Alabama.

The third belt borders a "V"-shaped area of the Chickamauga formation extending from the Tennessee line south of Chattanooga for about nine miles.

The fourth belt occupies a narrow ridge along the eastern base of Lookout Mountain and extends parallel to the mountain into the southern portion of McLamore Cove, where it turns to the northeast and follows the western base of Pigeon Mountain encircling its northeast end. It extends to the southwest paralleling the eastern base of Pigeon and Lookout mountains into Alabama along what is known as Shinbone Ridge.

The fifth belt occupies Dirtseller Mountain and extends to the southwest into Alabama.

The eastern area occupies the crest of high mountains in the great Appalachian Valley and forms irregular areas on the eastern side of these mountains. In the mountains forming the extreme eastern belt the sandstones are so prominent and cover so much of the formation that they have been mapped as a separate member by Hayes. The formation occupies the crest of White Oak Mountain and Taylor Ridge and a considerable portion along the eastern sides of these mountains. It occupies considerable portions of Simms Mountain, Gaylor Ridge, Heath Mountain, Turnip Mountain, Lavender Mountain, Horseleg Mountain, Turkey Mountain, John Mountain, Horn Mountain, and Chattoogata Mountain.

Lithologic character.—The Rockwood formation consists of sandstones and shales with some conglomerates in the eastern area and some interbedded limestones in the western area. It has a thickness of about 600 feet in the western area, while it attains a thickness of 1,600 in the eastern area.

The formation to the west of Taylor Ridge consists essentially of olive green and yellowish-green shales with thin beds of interstratified fine grained brown sandstones, while in the valley of Lookout Creek some thin beds of interstratified limestones occur. A heavy bed of sandstone usually forms the base of the formation. This sandstone is often absent in the western area and in places it is so unconsolidated that it does not result in an important topographic feature.

The formation to the west of and including Taylor Ridge consists essentially of brown and red sandstones and interstratified yellowish-green and olive green shales. To the east of the mountains which make up and extend parallel to the Chattoogata Mountain the formation has been divided by Hayes[1] into three parts. The lower portion of the formation consists of thin bedded purple sandstones with some yellow sandy shales. The middle portion consists of heavy bedded sandstones with some interstratified shales and with coarse sandstone and conglomerate from 50 to 75 feet thick, forming the sharp crests of the ridges. The upper portion of the formation consists of yellow shales and coarse sandstones.

Paleontology.—Below are given some of the more abundant fossile observed by the writer.

Corals	Pelecypods
Brachiopods	Gastropods
Cemarotoechia sp.	Trilobites
Pentamerous sp.	Crinoids
Schizophoria sp.	

[1]Hayes, C. W., Ringgold folio (No. 2), Geol. Atlas U. S., U. S. Geol. Survey, 1894.

Devonian

The rocks which constitute the Devonian in Georgia are made up of cherts, sandstones and shales.

During middle and upper Silurian time the Appalachian Valley region of Georgia was raised into a land surface and a great period of erosion followed. This widespread emergence continued into the Devonian and was more or less oscillatory during early Devonian time, becoming more pronounced in late Devonian. While the sea was oscillatory in Lower Devonian time sandstones and cherts with some shales, the remains of which now form the Armuchee chert, were deposited. During Upper Devonian time a gradual transgression of the Appalachian sea took place extending from the northeast to the southwest. The Chattanooga black shale was deposited unconformably upon the Armuchee chert in Georgia wherever that formation was present, and when not, it was laid down upon the Rockwood formation of Silurian age. The waters were shallow, and clastic deposits alone were formed.

The fauna contained in the Devonian rocks of Georgia is sparse.

ARMUCHEE CHERT

The Armuchee chert is thought by Hayes[1] to be equivalent in age to the Frog Mountain sandstone (Oriskany) which occurs in the southwest corner of the Rome quadrangle. Its greatest thickness in Georgia is 40 feet[2].

Areal distribution.—This formation occurs in a number of small areas in the northwestern portion of the Appalachian Valley. A small narrow area surrounds the northeastern and northwestern portions of Horseleg Mountain and extends to the northeast to the vicinity of West Rome. A third area occupies the center of Turkey Mountain, extending in a northwest direction to a point just west of Crystal Springs, where it turns to the west and extends to Taylor Ridge, and then to the north paralleling the east side of this ridge. It also occurs

[1]Hayes, C. W., Rome folio (No. 78), Geol. Atlas U. S., U. S. Geol. Survey, 1902.
[2]Ibid.

in John and Horn mountains and extends for 10 or 15 miles to the north of the southern terminus of John Mountain.

Lithologic character.—The formation consists primarily of bedded chert and at times is made up of reddish-brown sandstone.

Paleontology.—The Armuchee chert contains fossils of Oriskany age, according to Hayes[1].

CHATTANOOGA BLACK SHALE

The Chattanooga black shale is all that is left of the Upper Devonian deposits of Georgia. It seldom attains a thickness of more than 20 feet in this State.

Areal distribution.—The black shale always occupies a long narrow area, wherever it occurs, and lies upon the Armuchee chert of Lower Devonian age; and when this formation is absent, it lies upon the Rockwood formation of Silurian age.

Two parallel belts extend down the valley of Lookout Creek into Alabama. It encircles the Rockwood formation in Johnson Crook and extends to the south in two parallel belts into Alabama. Another belt extends from a point about four miles south of Chattanooga east of Lookout Mountain to the southern extremity of McLamore Cove, where it turns to the northeast and extends around the northeast point of Pigeon Mountain and then parallels the eastern side of Pigeon and Lookout mountains to the southwest.

In the southwestern corner of Chattooga County, an irregular, narrow, sinuous area extends from the Alabama line to the northeast along the southern portion of Gaylor Ridge. It surrounds the northeast extension of Horseleg Mountain and occupies small areas just west of Armuchee and in Turkey Mountain, and irregular and small areas to the east of Taylor Ridge along the northeast end of Simms Mountain, and in the southern portion of John and Horn mountains.

Lithologic character.—The Chattanooga shale contains at times a sandstone bed at the base of the formation which is of a dark gray color, fine grained, fetid, and contains *Lingula* sp. often in abundance. Above the sandstone occurs a jet black fissile, tough, bituminous shale which generally contains grains and nodules of pyrite scattered through-

[1]Op cit.

out its mass and which occur at times in well defined layers. The upper portion of the formation usually consists of a blue or greenish clay-shale containing phosphatic concretions.

Paleontology.—The Chattanooga black shale contains, in Georgia, *Discina, Lingula, Chonetes, Goniatites?* etc., and resembles very closely the type of fauna contained in the Gennessee of New York. It also shows occasionally fragmentary remains of plants.

CARBONIFEROUS

The Carboniferous has been divided by geologists into the lower and upper Carboniferous and these have been respectively termed the Mississippian and Pennsylvanian.

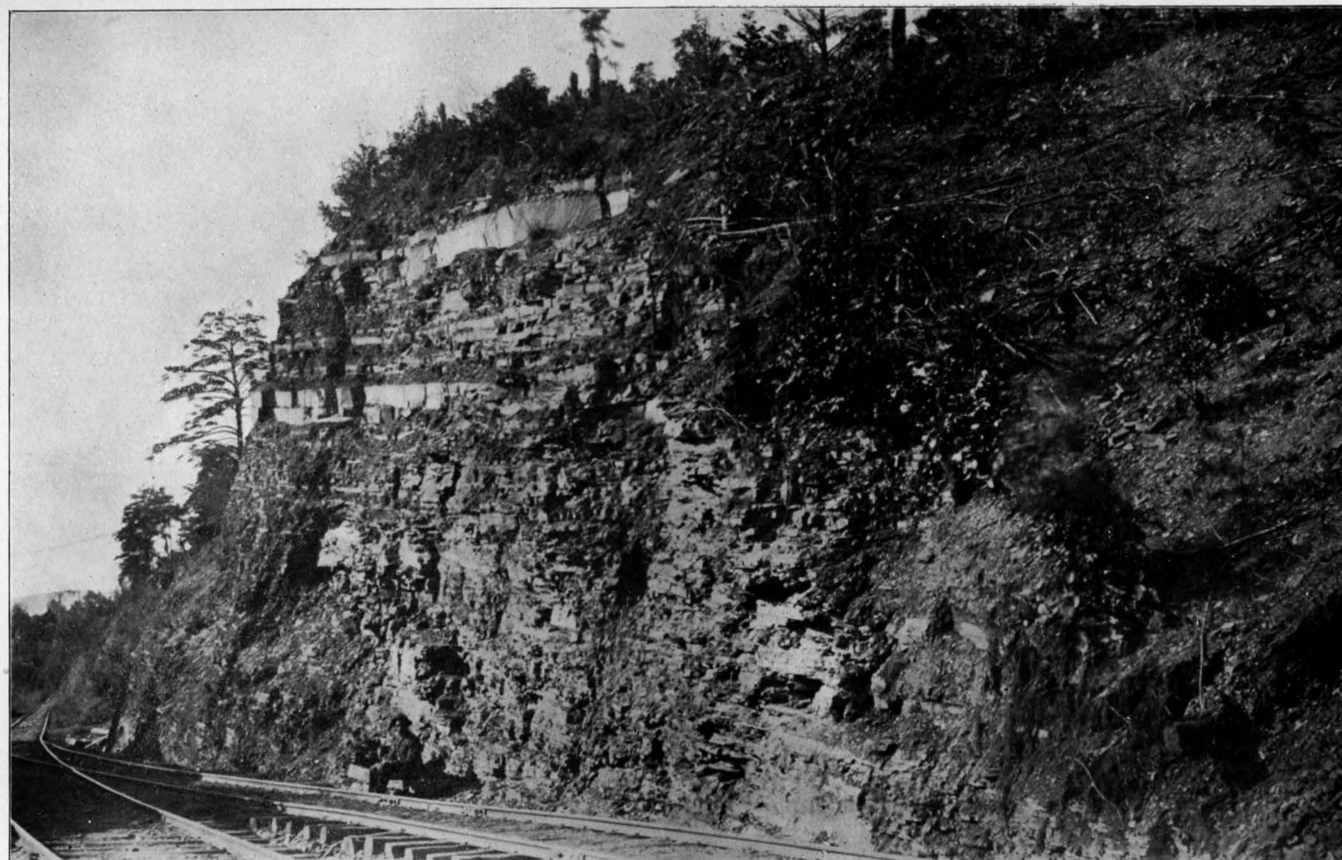
MISSISSIPPIAN

During the early part of Mississippian time the southern portion of the Appalachian Valley was marked by a continuation of the southeastern transgression of the sea that characterized the Upper Devonian. The Chattanooga black shale of the Upper Devonian is overlain by the Fort Payne chert, above which lies the Bangor limestone in the western portion of the Appalachian region; while in the Eastern area the Fort Payne chert is immediately succeeded by the Floyd shales and limestones. The Oxmoor sandstone appears to lie unconformably upon the Floyd shale.

FORT PAYNE CHERT

The Fort Payne chert lies unconformably upon the Chattanooga, black shale when that formation is present, and when it is absent it lies unconformably upon the Rockwood formation of Silurian age. It reaches a thickness of 200 feet.

Areal distribution.—The formation occupies narrow belts in the western portion of the Appalachian Valley, while it covers wider areas along the eastern side of Horn, John, and Chattoogata mountains. It does not occur in the eastern portion of the great Appalachian Valley of Georgia. The formation occupies approximately two parallel belts on both the eastern and western sides of the valley of Lookout Creek and extends to the south into Alabama.



A CUT ON THE CHATTANOOGA SOUTHERN RAILROAD AT ESTELLE, WALKER COUNTY, GEORGIA, SHOWING SHALES AND SANDSTONES ASSOCIATED WITH THE FOSSIL IRON ORES.

A narrow area parallels the eastern side of Lookout Mountain extending from the Tennessee line to the southern end of McLamore Cove, and thence to the northeast around Pigeon Mountain, paralleling the east side of Pigeon and Lookout mountains.

On the east side of Taylor Ridge the formation occupies irregular narrow belts and in the vicinity of Subligna the formation extends to the northeast across the valley occupying a broad area. It continues south of Taylor Ridge around Simms Mountain and entirely encircles Lavender Mountain and the southern portion of Gaylor Ridge; and also occupies a small area in Heath Mountain.

Another area extends from the vicinity of Huffmaker station in Floyd County southwest to within a short distance of the Coosa River. It completely surrounds Turkey Mountain and occupies both narrow and broad irregular areas to the east of John, Horn, and Chattoogata mountains.

Lithologic character.—The Fort Payne chert consists essentially of siliceous limestone with layers and nodules of chert, which occur in such abundance in places as to make up almost entirely this formation. Along the extreme eastern outcrops, namely, to the east of Horseleg Mountain and the Chattoogata range, the formation consists of heavy bedded chert in a siliceous cement, while the upper portion of the formation consists of a somewhat porous sandstone, originally calcareous. West of Taylor Ridge, the lower portion of the formation consists essentially of chert, while the upper portion becomes more calcareous and gradually passes into the overlying Bangor limestone. The chert of this formation is distinguished from that of the Knox dolomite by the usual great abundance of crinoid stems it contains.

Paleontology.—Crinoids, etc., often occur in great abundance.

FLOYD FORMATION

The Floyd formation lies stratigraphically immediately upon the Fort Payne chert. It attains a thickness of 1,200 to 2,000 feet[1].

Areal distribution.—The Floyd formation is not known to occur

[1]Hayes, C. W., Rome folio (No. 78), Geol. Atlas U. S., U. S. Geol. Survey, 1902.

west of Taylor Ridge. The shales of the formation usually occupy broad valleys, while the limestones as a rule form long, narrow, low ridges. The formation enters the State just east of White Oak Mountain and extends to the south to a point about three miles west of Tunnel Hill. A canoe-shaped area occupies Houston Valley, and another small area occurs in the vicinity of Gordon Spring.

A broad area occupies west Armuchee Valley and is separated from the broad valley to the south by a belt of Fort Payne chert which extends across the valley to the northeast of Subligna and entirely encircles Little Sand Mountain.

A broad area occupies both Big and Little Texas valleys and extends to the northeast occupying a great irregular-shaped valley and thence to the north on the east side of John and Horn mountains. It forms the great valley to the northwest of Rome. A small valley area of the Floyd formation occurs on the west side of Gaylor Ridge and extends to the southwest into Alabama.

Lithologic character.—The Floyd formation consists of shales with some limestones which attain a thickness of 100 to 150 feet. The shales are black, brown, yellow, and dark blue in color and are in places somewhat arenaceous. The limestones are heavy-bedded and dark blue in color, containing some chert in the lower part, while the upper beds are somewhat siliceous with some pure limestones. The physical character of the limestone is so similar to those of the Bangor formation that they can not be distinguished lithologically.

Paleontology.—The limestones and some of the arenaceous shales are often highly fossiliferous. Both *Bryozoans* and *Brachiopods* occur at some points in great abundance.

OXMOOR SANDSTONE

After the deposition of those rocks which formed the Floyd formation, coarse sandstones and conglomerates were deposited, forming the Oxmoor sandstones. The formation reaches a thickness of 600 feet.

Areal distribution.—The formation forms Judy Mountain and entirely surrounds Rocky Mountain.

Lithologic character.—The formation in Judy Mountain consists of a coarse sandstone and conglomerate, while the area that surrounds Rocky Mountain consists of brown and white sandstones.

Paleontology.—Nothing is known regarding the fauna of these beds.

BANGOR FORMATION

The Bangor formation lies immediately above the Fort Payne Chert in the western portion of the Appalachian Valley, while to the east it lies immediately upon the Oxmoor sandstone. It occupies stratigraphically the same position in the western portion of the Appalachian Valley that the Floyd formation occupies in the eastern portion. The formation, as described by Hayes[1], includes both limestones and shales. These limestones and shales have never been separated in Georgia, although the line of division between these rocks is very sharp, and the great variation in thickness of the limestones, as well as the shales, indicates an unconformity at the top of the limestones and at the top of the shales. The formation in Georgia reaches a thickness of 1,000 feet.

Areal distribution.—In the extreme northwest corner of the State the Bangor formation occupies the valley of Nickajack Creek. The creek has cut into the Cumberland Plateau and has exposed the Bangor formation which extends from the valley floor up the mountain sides to the point where the Lookout sandstones form the bluff.

Along the west side of Sand Mountain and along the east and west sides of Lookout and Pigeon mountains the Bangor formation reaches from their base well up on the mountain sides and extends in long parallel belts across the State from Tennessee to Alabama. A small area has been mapped by Hayes as the Bangor about three miles northwest of Ringgold. Another area occupies the eastern and western sides of Little Sand Mountain and the formation entirely encircles Rocky Mountain.

Lithologic character.—The Bangor formation, consisting of limestones and shales, varies considerably in thickness within a small area. In the valley of Nickajack Creek the lower portion of the formation contains much nodular chert imbedded in a heavy-bedded dark bluish-

[1]Hayes, C. W., Rome folio (No. 78), Geol. Atlas U. S., U. S. Geol. Survey, 1902.

gray, high-calcium limestone, while the upper beds at this point are largely concealed. Along the eastern side of Sand Mountain the Bangor formation consists of limestones in the lower portion of the formation and they reach a thickness of 800 feet, while the shales in the upper portion are largely concealed by the soil derived from these shales and the float derived from the overlying formations. The limestones of the Bangor formation in this area are only occasionally exposed over the mountain side and contain a very considerable amount of nodular chert imbedded in a heavy-bedded dark grayish-blue, high-calcium limestone. The limestone also contains many beds of interstratified, fine-grained, dark-blue, magnesian limestone.

Along the western side of Lookout Mountain the lower portion of the Bangor limestone contains a considerable amount of chert while the upper portion is largely free from chert. The limestone also contains some argillaceous and interstratified magnesian limestone. The shales are yellowish-green, red, carbonaceous, black, and brown.

The limestones along the eastern side of Lookout Mountain near the Tennessee line are very thin and are succeeded by a considerable thickness of shales (Pennington) which have been included in this formation. As we proceed to the south the limestones become thicker.

Pigeon Mountain, which is a spur of Lookout Mountain, contains the greatest thickness of the Bangor limestone in the Appalachian Valley region of Georgia. At this point the limestones reach a thickness of 900 feet, while they are overlain directly by the Lookout sandstones and shales. In the northern portion of the mountain the overlying formations have been entirely eroded away and have left the Bangor limestones forming a mountain of 800 to 900 feet in height without a covering. The Bangor limestones to the east of Lookout Mountain is largely free of chert. The formation attains a thickness in Little Sand Mountain of about 500 feet.

Paleontology—The limestones and shales of the Bangor formation usually contain an abundant fauna. The following were observed by the writer.

Corals
Crinoids
Blastoids
  Pentamerites maccalliei (Schuchert)
Bryozoa
  Archimedes sp.
Brachiopods
  Productus, sp.
  Spirifer sp.
  Rhynchonella sp.
Gastropods
  Pleurotomoria sp.
  Bellerophon sp.

PENNSYLVANIAN

The upper Carboniferous or Pennsylvanian is represented in Georgia by the Lookout sandstones and shales and the Walden sandstones and shales. The upper line of division between the Mississippian and the Pennsylvanian is marked throughout the greater part of the Southern Appalachian region by an unconformity. At the close of upper Mississippian time there was a general emergence of the Appalachian area, erosion followed and shallow seas predominated during Pennsylvanian time in which clastic sediments were deposited, consisting chiefly of conglomerates sandstones and shales with some thin-bedded limestones. Conditions were suitable for the deposition of coal deposits. The rocks in Georgia are indicative of near shore and estuarine deposits, while those rocks far to the west are indicative of marine deposition.

LOOKOUT FORMATION

The Lookout formation lies unconformably upon the Bangor limestones and shales and attains a thickness of from 400 to 500 feet in the western portion of the Appalachian Valley region, while in the eastern portion the remains of this formation are thinner.

Areal distribution.—The formation occupies a small area in the northern portion of Lookout Mountain south of Whiteside. A broad area extends southwest of Whiteside, occupying the vicinity of Cole City and extending to the south, forming the eastern bluffs of Sand Mountain. The formation forms the bluffs both on the east and west sides of Lookout Mountain and occupies the table land of Rocky and Little Sand mountains.

Lithologic character.—The formation consists of sandstones, conglomerates and shales with some commercial coal. The lower portion of the formation is made up of sandstone above which occur interbedded sandstones and shales succeeded by coarse sandstone and conglomerate. The upper limit of the formation is at the top of a heavy bed of sandstone and conglomerate which forms the cliff along Lookout Mountain.

Paleontology.—Little is known of the fauna of this formation in Georgia.

WALDEN SANDSTONE

The Walden sandstone includes all those sandstones and shales which lie above the Lookout formation in Georgia. The original thickness of the Walden formation is not known for the upper portion of the formation, which consists largely of shales, has been extensively eroded. It reaches a maximum thickness of 930 feet in the Lookout Mountain syncline.

Areal distribution.—This formation is confined to the western portion of the Appalachian Valley region in the synclines of Sand and Lookout mountains.

Lithologic character.—The formation is made up of sandstones, conglomerates and shales with several beds of commercial coal.

Paleontology.—Ferns and other plant remains are common in different localities but so far they have not been studied in Georgia.

LIMESTONES AND CEMENT MATERIALS OF THE PIEDMONT PLATEAU AND APPALACHIAN MOUNTAIN AREAS IN GEORGIA

PIEDMONT PLATEAU

GEOLOGY

Magnesian limestones are found in the Piedmont Plateau area of Georgia in Stephens, Habersham, Hall, and Gwinnett counties. These limestones, which are an extension of the Oconee County limestones of South Carolina, enter Georgia at the mouth of Panther Creek in Stephens County. They extend up Panther Creek in a southwest direction, and outcrop at different points on both the north and south sides of the creek.

The limestones enter Habersham County at the mouth of Little Panther Creek, where they turn still more to the southwest and outcrop along the south side of Little Panther Creek. From this point they extend for about one-fourth mile up the southwest fork of Devil's Den Creek, where they finally become concealed by the overlying schist.

A small outcrop of limestone is found in Hall County about one mile east of Sulphur Springs station, near the public road leading to White Sulphur Springs. Another exposure of magnesian limestone occupies a more extensive area just southeast of Gainesville. A third exposure in Hall County occurs within the corporate limits of Flowery Branch, where it appears in a branch just east of the big spring.

The occurrence of limestone is reported by S. P. Jones, former assistant State geologist of Georgia, in Gwinnett County south of Suwanee.

The several outcroppings of limestone above referred to apparently all belong to the same formation, which is correlated with similar limestones of Cambrian age in South Carolina.

DESCRIPTION OF INDIVIDUAL LOCALITIES

STEPHENS COUNTY

One mile west of the mouth of Panther Creek.—Magnesian limestone is exposed over a stratigraphic thickness of 21 feet along the north side of Panther Creek at a point about one mile west of its mouth. The limestone is gray and massive and is both overlain and underlain by schist. The base of the limestone is not exposed at this point. This stone can only be won by mining, on account of the presence of the overlying schist. The strike is N. 40° E., the dip 40° S. E. The stone can best be used for concrete and road metal. The high content of magnesia is objectionable for use in the manufacture of Portland cement.

The following analyses shows the composition of an average sample taken over the entire exposure:

Analyses of Limestone from Panther Creek

(Sample No. 1.)

Lime (CaO)	27.10
Magnesia (MgO)	16.16
Alumina (Al_2O_3)	.40
Ferric oxide (Fe_2O_3)	1.32
Sulphur trioxide (SO_3)	.02
Phosphorus pentoxide (P_2O_5)	.02
Carbon dioxide (CO_2) and organic matter	38.65
Silica (SiO_2)	16.33
	100.00

HABERSHAM COUNTY

One-fourth mile south of the mouth of Little Panther Creek.—A grayish-blue massive magnesian limestone is exposed over a stratigraphic thickness of 61 feet along the southeast side of Little Panther Creek and at a point about one-fourth mile south of its mouth. The strike is N. 70° E., the dip 20° SE.

The stone carries some pyrite. The high percentage of magnesia makes it objectionable for use in the manufacture of Portland cement, and its high content of silica renders it undesirable for agricultural purposes. The stone will make an entirely satisfactory lime for mortars and plasters, and can also be used for road metal, ballast and concrete.

The following analysis shows the composition of an average sample taken over the entire exposure:

Analysis of Limestone, from One-Fourth Mile South of the Mouth of Panther Creek (Sample No. 2)

Lime (CaO)	27.04
Magnesia (MgO)	15.22
Alumina (Al_2O_3)	.75
Ferric oxide (Fe_2O_3)	2.05
Sulphur trioxide (SO_3)	.08
Phosphorus pentoxide (P_2O_5)	.05
Carbon dioxide (CO_2) and organic matter	37.43
Silica (SiO_2)	17.38
	100.00

"Billy Walker" quarry.—The "Billy Walker" quarry is located on the property of W. L. Walker about 2½ miles southwest of the mouth of Panther Creek along the southeast side of the Turnerville public road. The rock is a gray, massive, magnesian limestone. Lime has been burned at this point for local use for more than 30 years. One circular stone kiln of the mixed feed type is in use. The kiln is 19 feet in height and 12 feet in diameter.

The high percentage of magnesia contained in this stone renders it objectionable for use in the manufacture of Portland cement and its high siliceous content results in a rather low grade agricultural lime. It is well suited, however, for mortars and plasters, concrete, road metal and ballast. The strike is N. 65° E., and the dip 33° SE.

The following section, from top to bottom, shows the physical character of the rock exposed at this point:

Section, "Billy Walker" Quarry, Habersham County

Sample No.	Unit No.	Description of Units	Thickness feet	Total Thickness feet
	3	Green schist		
	2	Porous brown, argillaceous sandstone originally calcareous and probably fossiliferous	2	15
3	1	Gray and grayish-blue dolomite	13	13

The following analysis shows the average composition of the dolomite exposure:

Analysis of Dolomite from "Billy Walker" Quarry

(Sample No. 3; Unit No. 1)

Lime (CaO)	28.88
Magnesia (MgO)	18.88
Alumina (Al_2O_3)	.60
Ferric oxide (Fe_2O_3)	1.20
Sulphur trioxide (SO_3)	.02
Phosphorus pentoxide (P_2O_5)	.04
Carbon dioxide (CO_2) and organic matter	44.64
Silica (SiO_2)	5.74
	100.00

Hall County

Quarries of C. L. Deal Manufacturing Company.—The quarries of the C. L. Deal Manufacturing Company are located about two miles south of Gainesville near the Southern Railroad.

The magnesian limestone is overlain and underlain by a schist. The schist which formerly overlaid the limestone has been removed by erosion. The base of the formation is nowhere exposed. The strike is N. 77° E., and the dip is 10° to 20° NW.

The physical character of the magnesian limestone found at the Deal quarries is shown in the following sections. The limestone has been somewhat concealed by the falling in of residual soil at quarry No. 1, so that no section of this quarry is given.

Section of Quarry No. 2, C. L. Deal Manufacturing Company, Near Gainesville, Hall County

Sample No.	Unit No.	Description of Units	Thickness feet	Total Thickness feet
	3	Residual material	10	45
	2	Siliceous limestone	10	35
4	1	Grayish-white and gray limestone	25	25

Section of Quarry No. 3, C. L. Deal Manufacturing Company, Near Gainesville, Hall County

Sample No.	Unit No.	Description of Units	Thickness feet	Total Thickness feet
	2	Residual overburden	10	70
5	1	Gray and grayish-white limestone (partly concealed—about 25 feet exposed)	60	60

CONDITIONS AFFECTING DEVELOPMENT

The quarry openings have been made in the hillsides at points where the greatest horizontal and vertical exposure of the rock could be secured. The tonnage of the limestone above the general level of the valley could be determined; however, as the base of the formation is nowhere exposed it is not known just how thick the formation is at this point, and consequently the total amount of rock available could not be determined without some prospecting. There is sufficient limestone occupying a broad area to supply the material for an extenisve lime and crushed stone plant for a number of years. It is most important to know at what points quarries can be located where the overburden of residual material and leached limestone is thin so that the stone can be won at a reasonable cost.

DEVELOPMENT

Limestone has been quarried and burnt into lime on the C. L. Deal Manufacturing Company's property since 1864. There are two stone kilns now in use 25 feet in height and 8 feet in diameter at the bottom and 6 feet at the top. Each kiln is provided with two firing boxes at a point about 6 feet above the draw box. The kilns are fired with wood and have a total capacity of about 200 barrels in twenty-four hours. The limestone can best be used for commercial lime, ballast, road metal, and concrete.

The following analyses show the composition of the limestone exposed in quarries 2 and 3:

Analyses of Limestone from Quarries 2 and 3, the C. L. Deal Manufacturing Company, Near Gainesville

Quarry No.	2	3
Sample No.	4	5
Unit No.	1	1
Lime (CaO)	28.00	30.02
Magnesia (MgO)	16.06	17.98
Alumina (Al_2O_3)	.80	.60
Ferric oxide (Fe_2O_3)	1.25	1.70
Sulphur trioxide (SO_3)	tr.	.02
Phosphorus pentoxide (P_2O_5)	.04	.06
Carbon dioxide (CO_2) and organic matter	39.65	42.79
Silica (SiO_2)	14.20	6.83
	100.00	100.00

Flowery Branch.—Argillaceous, magnesian limestone is exposed over not more than ten stratigraphic feet along the valley of Flowery Branch in the town of the same name about 200 feet north of the big spring. The stone is too high in magnesia to be of any value for use in the manufacture of Portland cement. The high content of silica makes it objectionable for lime, even locally. The stone might be used for road material.

The following analysis shows the composition of an average sample taken over the entire exposure:

Analysis of Limestone from Flowery Branch

(Sample No. 6)

Lime (CaO)	29.72
Magnesia (MgO)	8.48
Alumina (Al_2O_3)	.35
Ferric oxide (Fe_2O_3)	1.20
Sulphur trioxide (SO_3)	.03
Phosphorus pentoxide (P_2O_5)	.03
Carbon dioxide (CO_2) and organic matter	33.32
Silica (SiO_2)	26.87
	100.00

APPALACHIAN MOUNTAINS

The only calcareous material of the Appalachian Mountain area of Georgia suitable for lime and cements are the Murphy Marbles, which extend from the Georgia-North Carolina line near Culberson, southward through Fannin, Gilmer, Pickens, and Cherokee counties.

FANNIN COUNTY

GEOLOGY

The Murphy Marbles enter Fannin County from North Carolina in the extreme northeast corner of the county along two parallel belts separated by a fault.

The most eastern belt of marble outcrops near the headwaters of Hamestring Creek and extends to the southwest, occupying the valley immediately west of High Top Mountain. The marble is again exposed along the valley of Cutcane Creek and extends from the headwaters of this creek to the junction of Cutcane and Tempton creeks. One mile east of Blue Ridge occasional outcrops of marble occur along Weaver Creek.

Marble occupies the narrow valley along Rapier Mill Creek in the vicinity of Sweet Gum post office. It follows this valley to the southwest and is exposed at Arp Spring. The marbles are again exposed in the valley of Young Stone Creek near Coles crossing.

Marble was exposed in the excavation work made in the construction of the bridge three-fourths mile southwest of Mineral Bluff at the point where the Louisville & Nashville railroad crosses Toccoa River. Another small exposure of marble occurs one mile southwest of Blue Ridge on the county poorhouse farm.

The marbles of Fannin County are all finely crystalline and contain many impurities which consist largely of the silicates, tremolite and talc. These minerals are best developed along the planes of schistosity, which apparently correspond to the bedding planes.

The predominating color of the marble, is white; however, some flesh-colored and dark-gray and black banded marbles also occur.

The Murphy marble in this county is seldom exposed for more than several stratigraphic feet. It occupies the valley areas and is usually overlain by a thick residual soil.

The marble of Fannin County is highly magnesian and cannot therefore be used in the manufacture of Portland cement. They may, however, be used in the manufacture of lime for local purposes and as crushed rock for road metal and ballast.

Description of Individual Localities

Prof. S. W. McCallie, in his report on the marbles of Georgia, gives two analyses of marbles in Fannin County. His description and analyses are as follows:

One mile east of Mineral Bluff.—Marble is found in a somewhat hilly section, close to the road leading to Morganton. It occurs here about five feet below the surface at the foot of a hill near a small stream where recently it has been extensively prospected. Two excavations only a few yards apart, each about 20 feet square and 10 feet deep, have been cut into the marble by means of channeling machines and many large blocks have been taken out. Some of these still remain above the excavation, but most of them have been used for making lime. The marble from one of these openings has a very fine texture and a snow-white color, but mica occurs in some of the layers in such abundance as to cause them to split quite easily along certain lines. In the other opening the marble seems to be sounder and of a darker color, but it all contains both mica and hornblend.

The following analysis[1] shows the chemical composition of the marbles at this point.

Analysis of Marble from One Mile East of Mineral Bluff

(Sample No. 7)

Lime (CaO)	31.89
Magnesia (MgO)	19.64
Alumina (Al_2O_3) } Ferric oxide (Fe_2O_3) }	.74
Silica (SiO_2)	1.73
Loss on ignition	46.00
	100.00

The Dickey property.[2]—While the workmen were engaged a few years ago in making the excavation for the bridge piers of the Marietta and North Georgia railroad at Toccoa River, marble was discovered near water level. Since then a large pit, about 30 feet square and 15 feet deep, has been dug

[1]Analysis by Dr. W. H. Emerson.

[2]McCallie, S. W., Marbles of Georgia: Bull. Geol. Survey of Ga., No. 1, 1907, pp. 41-42.

just below the bridge, in order to expose the marble. As the bottom of the pit lies below the surface of the river, and is usually covered with water, it was found to be impracticable at the time of our visit to make an examination of the stone in situ. It was learned, however, that the marble at the bottom of the opening was not a continuous mass, but it appeared to be in large boulders. * * * * Specimens of the stone contained numerous cutters and seams and is generally unsound. All the marble found at this place is of a light color and a rather fine texture, and has comparatively few impurities.

The following analysis[1] shows the chemical composition of the marble at this point:

Analysis of Limestone from the Dickey Property

(Sample No. 8)

Lime (CaO)	31.53
Magnesia (MgO)	21.30
Alumina (Al_2O_3) / Ferric oxide (Fe_2O_3)	.24
Silica (SiO_2)	.10
Loss on ignition	47.26
	100.43

GILMER COUNTY

Geology

The Murphy marble enters the northern portion of Gilmer County along the valley of Rock Creek to the west of Cherry Log post office. Marbel also occurs in the valley of Whitepath Creek and the valleys of Big and Little Turniptown creeks near the Louisville & Nashville Railroad trestle. The marble is again exposed along the west side of Talona Creek at Tioga station, and extends down this valley into Pickens County.

The marbles of Gilmer County are all fine, crystalline and compact, with the exception of some coarse crystalline, high-calcium marbles occurring in the lower portion of the formation at and near the Gilmer-Pickens County line. The marbles are usually white to gray in color, fine to coarse crystalline with mica, tremolite, talc, etc., occurring as impurities.

The magnesian marbles can not be used in the manufacture of

[1]Analysis by Dr. W. H. Emerson.

Portland cement. The high-calcium marbles, however, are chemically suitable for this purpose. The high-calcium stone may also be used for fluxing, copper smelting, manufacture of lime, road metal, and ballast. The magnesian marbles may be used in the manufacture of carbon dioxide, for crushed rock, flooring, and also for road metal, ballast, and the manufacture of lime.

Description of Individual Localities

Holt property.[1]—On the Holt farm, which joins the Whitaker property, marble outcrops at various places about the junction of Big and Little Turniptown creeks. Here the narrow valleys along the creeks become suddenly expanded into a wide fertile bottom nearly surrounded by high hills. Near the center of the bottom the marble outcrops in the creek at several places and is said to be found underlying a number of acres in the immediate vicinity. A small amount of stone has been quarried here to make lime, and at one place a corner-stone was secured for the school building at Ellijay, but otherwise the deposit is undeveloped.

The following analysis[2] shows the chemical composition of the marble at this point:

Analysis of Marble from the Holt Property

(Sample No. 9)

Lime (CaO)	31.61
Magnesia (MgO)	21.06
Alumina (Al_2O_3) / Ferric oxide (Fe_2O_3)	.78
Silica (SiO_2)	1.01
Loss on ignition	46.49
	100.95

North Georgia Marble Company.—The quarry of the North Georgia Marble Company is located at Tioga station, and on the west side of Talona Creek. The quarry was first opened in 1907. The entire output is shipped to Copper Hill, Tenn., to be used in the copper smelter. The marble is white, finely crystalline and takes a good polish. Stratification has been largely obliterated by pressure and crystallization, so that it may be possible to secure blocks of sufficient size for use as a commercial ornamental and building stone.

[1]McCallie, S. W., Marbles of Georgia: Bull. Geol. Survey of Ga. No. 1, 1907, pp. 45-46.

[2]Analysis by Dr. W. H. Emerson.

The quarry is 275 feet in length, and is worked in a direction parallel to the strike of the rock. Only a few stratigraphic feet of the formation are exposed.

The following is a chemical analysis of marble from the quarry of the North Georgia Marble Company:

Analysis of Marble, North Georgia Marble Company

(Sample No. 9a)[1]

Lime (CaO)	38.40
Magnesia (MgO)	14.07
Ferric oxide (Fe_2O_3)	1.28
Sulphur trioxide (SO_3)	tr.
Phosphorus pentoxide (P_2O_5)	.02
Silica (SiO_2)	.80
Clay bases (Alumina, Al_2O_3 and alkalies, Na_2O, K_2O)	.12
Loss on ignition	45.62
	100.21

PICKENS COUNTY

Geology

The Murphy marbles form high bluffs at the Gilmer-Pickens county line and occupy the valley of Talona Creek. They extend to the south as far as the mouth of Fisher's Creek. Fine grained, largely crystalline, grayish-blue limestone is exposed in places along the north bank of Fisher's Creek between the mouth of this creek and its headwaters. The marble outcrops at a point about two miles northeast of Jasper in the valley of Longswamp Creek. The formation etxends to the south, gradually becoming thinner and entirely disappearing at a point about two miles south of the Perseverance quarries.

The marbles occupy the eastern portion of the valley of the east branch of Longswamp Creek, and extend well up on the hillsides. They occupy the valley of Longswamp Creek in the vicinity of Tate post office and follow the valley into Cherokee County.

The commercial marbles of Pickens County are all high-calcium stones. Magnesian marbles occur, but they are not used in the trade as marbles. They are utilized only for crushed-stone products, the

[1]Average sample for analysis furnished by Horace A. Field, Gen. Mgr.

manufacture of carbonic acid gas, and other purposes. The high-calcium marbles are chemically suitable for use in the manufacture of both a white and gray Portland cement, for fluxing purposes, manufacture of lime, road metal, ballast and concrete.

Description of Individual Localities

The King Marble Company.—The property of the King Marble Company is located about three-fourths mile north of Whitestone station, directly on the Louisville & Nashville railroad.

The rock is obtained from the lower portion of the formation and consists of both coarsely crystalline high-calcium and finely crystalline high-magnesian stone. The magnesian marble has been altered in many places into magnesian silicates. The quarry opening is in the valley; it was entirely filled with water at the time of the writer's visit.

On account of the association of the magnesian and the high-calcium marble, this stone is not suitable for use in the manufacture of Portland cement.

The following analyses show the character of the stone at this point:

Analyses of Marble from King Marble Company's Property

Sample No.	10[1]	11[2]
Lime (CaO)	53.00	39.10
Magnesia (MgO)	1.54	11.30
Alumina (Al_3O_3) / Ferric oxide (Fe_2O_3)	1.44	2.06
Sulphur trioxide (SO_2)	.00	.00
Phosphorus pentoxide (P_2O_5)	tr.	tr.
Silica (SiO_2)	1.00	4.60
Loss-on-ignition	43.02	42.94
	100.00	100.00

Detroit Marble Company.—The property of the Detroit Marble Company is located between Whitestone station and the Pickens-Gilmer county line, directly on the Louisville & Nashville railroad.

[1]Coarsely crystalline, high-calcium marble.
[2]Altered high-magnesian stone.

The Murphy marble is exposed in the quarry over a stratigraphic thickness of 30 feet. Beneath this lies ten feet of finely crystalline white and grayish-white magnesian stone, which is largely concealed at this point. Alteration of the stone has taken place along the bedding planes into magnesian silicates. The above unit is underlain by coarsely crystalline high-calcium marble. The Murphy marble is overlain by a mica schist, but the base of the formation is not exposed. The strike is N. 47° W. and the dip 28° NE.

After the rock is drilled and blasted from place, it is broken intc convenient size for handling, loaded on wheelbarrows and wheeled to the crusher. The stone is fed by hand or shovel into a small Blake jaw-crusher. The crushed rock passes down a chute and over a fine sieve which separates the stone from the dust and then over a three-eighths inch screen. The rock which passes over the screen is carried by gravity to two small Allis Chalmers gyratory crushers. The crushed stone passes through a combination screen with both round and oblong openings; one-fourth inch ring gives size No. 1; three-eighths inch ring gives No. 2; and one-half inch ring gives No. 3.

The stone is locally known with the trade as "whitestone." It is used, when crushed, primarily for flooring. The dust can be used in the manufacture of carbonic acid gas, epsom salts, for agricultural and many other purposes.

The following analysis represents the composition of an average sample taken over the upper 30 feet of the exposure:

Analysis of Marble from Detroit Marble Company Property
(Sample No. 12)

Lime (CaO)	32.04
Magnesia (MgO)	18.00
Alumina (Al_2O_3) } Ferric oxide (Fe_2O_3) }	1.88
Sulphur trioxide (SO_3)	.00
Phosphorus pentoxide (P_2O_5)	tr.
Silica (SiO_2)	4.73
Loss on ignition	43.35
	100.00

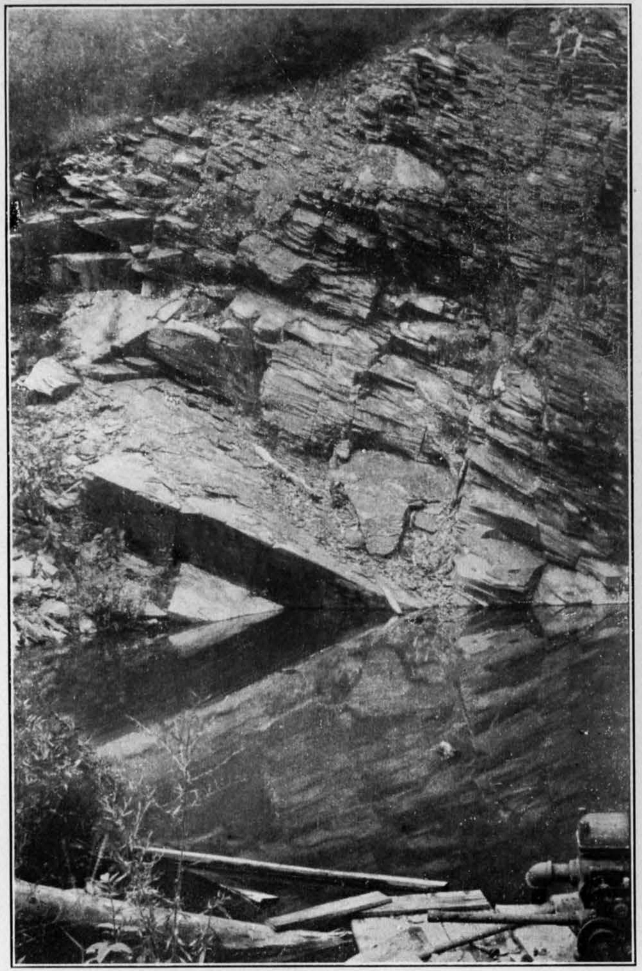
Whitestone Marble Company.—The property of the Whitestone Marble Company is located at Whitestone, directly on the Louisville & Nashville railroad. The Murphy marble at this point is a high-magnesian stone, white to grayish-white and thin bedded. An alteration of the marble into magnesian silicates has taken place, especially along the bedding planes. The strike is N. 32° W., and the dip is 15° NE.

The stone is drilled and shot from place; then broken by sledge into convenient size to be handled by the miner and loaded on cars which are hoisted along an incline to a small Gates crusher (No. 2). From the crusher it is conveyed to rolls and thence to a pulverizer. The white dust is sacked and shipped for the manufacture of carbonic acid gas and epsom salts. Crushed stone is also sold for flooring, etc. The high content of magnesia is objectionable in the manufacture of Portland cement.

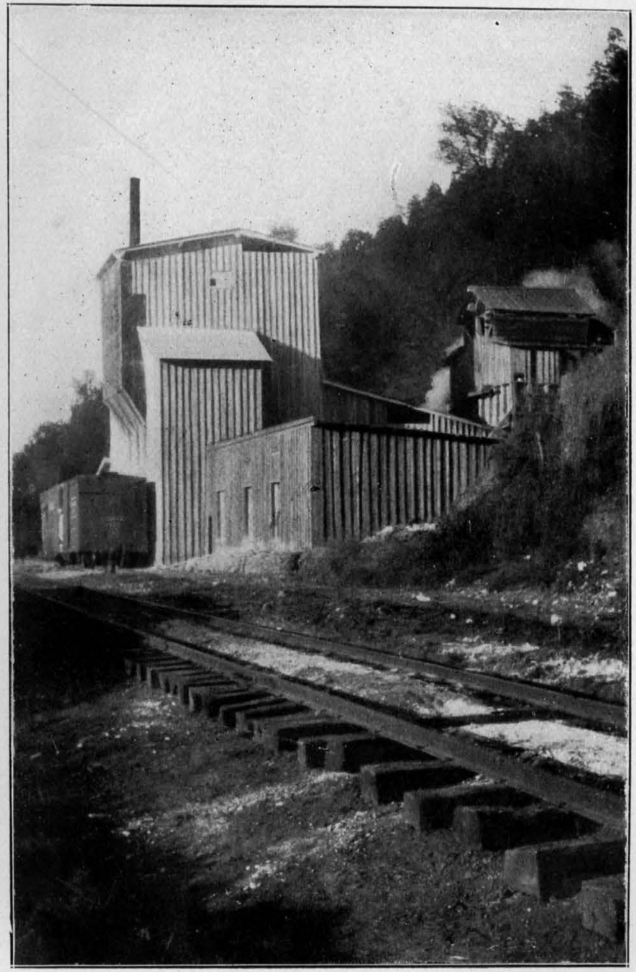
Section from Top to Bottom, Quarry of Whitestone Marble Company

Sample No.	Unit No.	Description of Units	Thickness feet	Total Thickness feet
13	4	Finely crystalline, grayish-white magnesian marble. Thin scales of magnesian silicates occur along the bedding planes	12.5	51.5
14	3	Same as unit 4	6	39
15	2	Finely crystalline, white magnesian marble with some alteration into magnesian silicates	18	33
16	1	Fine crystalline, white magnesian marble	15	15

The following analyses show the composition of the units described in the above section:



A. ROCKMART SLATES. QUARRY OF THE ROCKMART SHALE BRICK AND SLATE COMPANY, ROCKMART, POLK COUNTY, GEORGIA



B. MILL OF THE WHITESTONE MARBLE COMPANY, WHITESTONE, PICKENS COUNTY, GEORGIA. QUARRY LOCATED IMMEDIATELY EAST OF THE MILL

Analyses of Marble from Whitestone Marble Company

Sample No.	13	14	15	16
Unit No.	4	3	2	1
Lime (CaO)	34.58	33.74	37.50	58.00
Magnesia (MgO)	15.80	16.65	15.60	17.94
Alumina (Al_2O_3), Ferric oxide (Fe_2O_3)	1.46	1.40	1.58	1.16
Sulphur trioxide (SO_3)	.00	.00	.00	.00
Phosphorus pentoxide (P_2O_5)	tr.	.01	tr.	tr.
Silica (SiO_2)	4.06	6.15	8.58	3.24
Loss on ignition	44.10	42.05	36.74	19.66
	100.00	100.00	100.00	100.00

Crystal Marble Company.—The property of the Crystal Marble Company is situated on the east side of the Louisville & Nashville railroad 1,500 feet south of Whitestone.

The marbles are exposed from the base of the overlying schist for 36 feet, below which they are largely concealed by quarry waste. The strike is N. 25° W., and the dip 15° NE.

The stone is blasted from place and broken by sledge to a size convenient to be handled by the quarryman. It is then loaded in wheelbarrows and dumped into an incline gravity chute which carries it to a small Gates crusher. The crushed stone is passed through a number of screens and sold for flooring, etc.

Section from Top to Bottom, Quarry of Crystal Marble Company

Sample No.	Unit No.	Description of Units	Thickness feet	Total Thickness feet
17	3	Massive pink and white marble	17.6	84.7
18	2	Finely crystalline white marble with bluish and greenish cast	18.8	67.1
	1	Concealed	48.3	48.3
		Railroad	0.0	0.0

The following analyses show the composition of the units exposed in the above section:

Analyses of Marble from Crystal Marble Company

Sample No.	17	18
Unit No.	3	2
Lime (CaO)	41.42	34.30
Magnesia (MgO)	9.66	17.02
Alumina (Al_2O_3) / Ferric oxide (Fe_2O_3)	1.44	1.96
Sulphur trioxide (SO_3)	.00	3.20
Phosphorus pentoxide (P_2O_5)	tr.	tr.
Silica (SiO_2)	8.10	3.43
Loss on ignition	39.38	40.09
	100.00	100.00

Two miles northeast of Jasper.—The Murphy marble is exposed over a stratigraphic thickness of about 20 feet in an old quarry at a point about two miles northeast of Jasper, along the east side of the east fork of Longswamp Creek. The quarries were first opened in 1884. The strike is N. 5° E., and the dip 37° SE.

The following analysis of sample represents the average content of the entire exposure with the exception of the upper impure sandy layers:

Analyses of Marble, Two Miles Northeast of Jasper

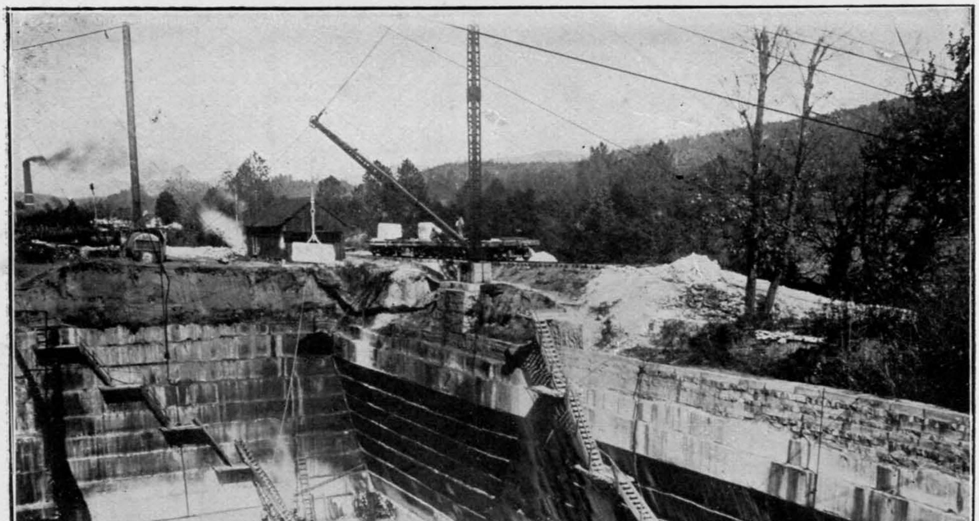
(Sample No. 19)

Lime (CaO)	32.74
Magnesia (MgO)	16.75
Alumina (Al_2O_3) / Ferric oxide (Fe_2O_3)	.94
Sulphur trioxide (SO_3)	.00
Phosphorus pentoxide (P_2O_5)	tr.
Silica (SiO_2)	5.60
Loss on ignition	43.97
	100.00

The Perseverance quarry.—The Perseverance quarry is located about 1¾ miles east of Jasper on the east side of Longswamp Creek.

The upper portion of the Murphy marble is exposed, while the

A. MURPHY MARBLE, DETROIT MARBLE COMPANY, WHITESTONE, GEORGIA



B. QUARRY OF THE GEORGIA MARBLE COMPANY, NEAR TATE, PICKENS COUNTY, GEORGIA middle and lower portions of the formation in the valley of Longswamp Creek are seldom seen. The stone is white, finely crystalline, thin-bedded, and highly magnesian. Brown mica (phlogopite) is the most abundant accessory impurity. In some of the beds leaching has taken place and lime and magnesia have been carried away in solution in underground waters leaving small caves.

The stratigraphic thickness of the Murphy marble at this point is 225 feet. The strike is N. 20° E., and the dip 22° S.E.

The following analysis represents an average sample taken over the entire exposure:

Analysis of Marble from the Perseverance Quarry
(Sample No. 20)

Lime (CaO)	34.68
Magnesia (MgO)	16.10
Alumina (Al_2O_3) } Ferric oxide (Fe_2O_3) }	1.56
Sulphur trioxide (SO_3)	.00
Phosphorus pentoxide (P_2O_5)	tr.
Silica (SiO_2)	3.05
Loss on ignition	44.61
	100.00

Georgia Marble Company.—The quarries of the Georgia Marble Company are located along the valley of Longswamp Creek in the vicinity of Tate post office. Quarries are also operated by this company along the south bluff paralleling the east branch of Longswamp Creek at a point about one-half mile west of Marble Hill post office.

The Murphy marble occupies a broad valley in the vicinity of Tate post office, narrowing immediately to the south. Along the west side of the valley the marbles are standing on end, that is, dipping at 90°. Crystallization and recrystallization of the marbles in this vicinity have removed all traces of bedding: however, the bedding can be determined from the relation of the marble to the adjacent schist.

The impurities originally contained in the formation have crystallized out in the form of graphite, hematite, mica, etc. The graphite interspersed throughout the white marble produces the "Creole," while the finely divided hematite results in the various shades of pink, known to the trade as "Etowah." The marbles which occur along the valley of the east branch of Longswamp Creek are white. One-half mile south of Tate post office the strike is N. 45° W., and the dip 72° SW.

The marbles, in addition to use as a building and monumental stone, are chemically suitable for use in the manufacture of both white and gray Portland cement; in the manufacture of lime, both for structural and agricultural purposes; for fluxing, etc.

The following analyses show the composition of two samples which were taken for an average of the quarries of this company:

Analyses of Marble from Georgia Marble Company

Sample No.	21	22
Lime (CaO)	53.96	54.00
Magnesia (MgO)	1.00	.89
Alumina (Al_2O_3) / Ferric oxide (Fe_2O_3)	1.76	1.38
Sulphur trioxide (SO_3)	.00	.00
Phosphorus pentoxide (P_2O_5)	.02	tr.
Silica (SiO_2)	1.25	1.84
Loss on ignition	42.01	41.89
	100.00	100.00

Southern Marble Company.—The quarries of the Southern Marble Company are located in the immediate vicinity of Marble Hill post office along the bluffs which parallel the south side of the east branch of Longswamp Creek.

The Murphy marble occupies the valley along the south side of the creek and extends often more than 100 feet up the bluff. It is a white, coarsely crystalline and massive stone, containing few accessory impurities. The formation attains a thickness of at least 200 stratigraphic feet. The strike is N. 80° E., and the dip 20° SE.

The following analysis represents the composition of an average sample of the Murphy marble taken over the entire exposure at Marble Hill:

Analysis of Marble from Southern Marble Company
(Sample No. 23)

Lime (CaO)	53.04
Magnesia (MgO)	1.00
Alumina (Al_2O_3) / Ferric oxide (Fe_2O_3)	1.32
Sulphur trioxide (SO_3)	.00
Phosphorus pentoxide (P_2O_5)	.02
Silica (SiO_2)	1.41
Loss on ignition	43.21
	100.00

Amicalola Marble Quarries.—The quarries of the Amicalola Marble Company are located one mile south of Marble Hill post office in the valley of a small tributary to the east fork of Longswamp Creek. The marble is usually concealed by an overburden of material derived from the adjacent formations. The stone is extremely white. The following accessory minerals are found in certain portions of the formation: tremolite, mica, and graphite, with some intrusive hornblende. The dip is 15° SE.

Besides the use of this stone for commercial marble, it is of suitable composition for use in the manufacture of both gray and white Portland cement, for fluxing purposes, lime, and many crushed stone products.

The following analysis shows the average composition of this marble:

Analysis of Marble from the Amicalola Quarries
(Sample No. 24)

Lime (CaO)	52.13
Magnesia (MgO)	2.35
Alumina (Al_2O_3) / Ferric oxide (Fe_2O_3)	.86
Sulphur trioxide (SO_3)	.00
Phosphorus pentoxide (P_2O_5)	tr.
Silica (SiO_2)	1.00
Loss on ignition	43.61
	100.00

CHEROKEE COUNTY

Geology

Occasional outcrops of Murphy marble have been observed in Cherokee County along the valley of Longswamp Creek immediately south of the Pickens-Cherokee county line. Outcrops also occur along the continuation of this belt between Ballground and Canton. Several miles west of Ballground and along Sharp Mountain Creek marble is again exposed. It extends to the southwest and outcrops along Hickory Log Creek.

The chemical and physical character of the formation varies not only in a direction parallel to the strike of the rocks, but also from the bottom to the top of the formation. The marbles are in places white and pink, coarsely crystalline, high-calcium stones; again they are dark colored, highly siliceous and micaceous or high-magnesian. They are seldom exposed over a thickness of more than fifteen stratigraphic feet. The thickness of the formation probably never exceeds 150 feet and in certain localities the formation thins down to only a few feet.

Description of Individual Localities

Seven miles northwest of Canton.—White, finely crystalline, magnesian marble of the Murphy formation outcrops at intervals over a stratigraphic thickness of 15 feet along the east side of Lost Town Creek at a point about seven miles northwest of Canton and about one-half mile north of the junction of Lost Town and Shoal creeks. The strike is N. 16° W., and the dip 20° NE.

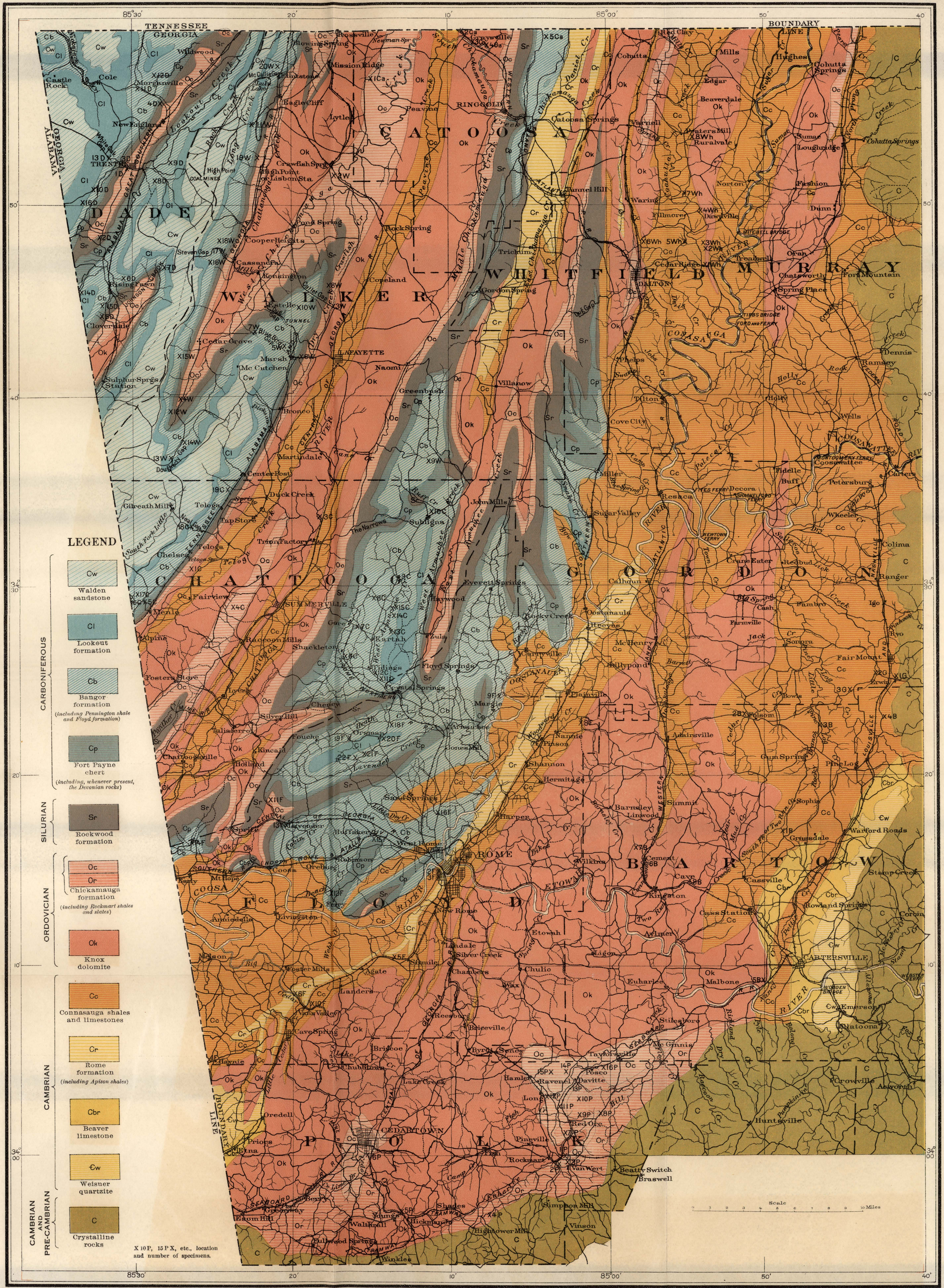
The following analysis[1] shows the composition of the stone at this point:

Analysis of Marble from Near Canton, Georgia

(Sample No. 25)

Lime (CaO)	24.07
Magnesia (MgO)	17.24
Alumina (Al_2O_3) Ferric oxide (Fe_2O_3)	.43
Silica (SiO_2)	21.76
Loss on ignition	37.08
	100.58

[1]McCallie, S. W., Marbles of Georgia: Bull. Geol. Survey of Ga. No. 1, 1907, p. 109.



GEOLOGICAL MAP OF APPALACHIAN VALLEY AND CUMBERLAND PLATEAU OF GEORGIA

COMPILED BY T. POOLE MAYNARD, ASSISTANT STATE GEOLOGIST, FROM FT. PAYNE, RINGGOLD AND ROME FOLIOS OF THE U. S. GEOLOGICAL SURVEY AND FIELD NOTES OF THE AUTHOR

1912

LIMESTONES AND CEMENT MATERIALS OF THE APPALACHIAN VALLEY AND CUMBERLAND PLATEAU AREAS IN GEORGIA

POLK COUNTY

GEOLOGY

Beaver Limestone

The Beaver limestone occurs at only one locality in Polk County, namely, on the northeast end of Indian Mountain, where it extends from the Georgia-Alabama line northeast to Oredell. The formation has a total length of about three miles and an average width of about three-fourths mile. The Beaver limestone is usually largely concealed by residual material. The high percentage of magnesia prevents its use in the manufacture of Portland cement, and its heavy overburden interferes with the commercial winning of the stone for lime and for crushed stone products.

Knox Dolomite

The Knox dolomite consists of heavy-bedded and massive, semicrystalline, gray dolomite, containing considerable chert above the lower 500 feet. The formation is seldom exposed in Polk County over any considerable thickness. The extensive residual materials due to the disintegrating weathering agencies usually conceal the underlying rock. There are but few exposures in Polk County of this formation which could be commercially won for the burning of lime. Its dolomitic character makes it objectionable for use in the manufacture of Portland cement. Both the chert and the dolomite of this formation can best be utilized in the construction of roads.

Chickamauga Formation

The Chickamauga formation has been divided by Hayes[1] into two members, the Chickamauga limestone, which is correlated with the lower portion of the Chickamauga formation north of the Coosa Valley, and the Rockmart shales and slates, which are considered to be the equivalent of the upper portion of the Chickamauga formation. These rocks in Polk County present wide differences in both the lithologic character and fossil content from the Chickamauga formation north of the Coosa Valley.

CHICKAMAUGA LIMESTONE

The Chickamauga limestone consists of dark-blue high-calcium limestone in the lower portion of the formation, succeeded by thin and heavy beds of interstratified dark blue, high-calcium, and light-gray to bluish-gray magnesian limestone. The limestone sometimes attains a thickness of 200 feet. The line of contact between the Chickamauga limestone and the Knox dolomite has not been observed in this county. The two formations are always separated by a band of red clay which marks the line of an unconformity between the two formations.

The high-calcium beds of the Chickamauga limestone, which occur in greater abundance in the lower portion of the formation are chemically suitable for use in the manufacture of Portland cement. Both high-calcium and magnesian beds occur in the upper portion of the formation; however, the magnesian limestones predominate. On the property of the Southern States Portland Cement Company, the limestones dip at a considerable angle, so that the high-calcium beds can be won by quarrying in a direction parallel to the strike of the rock. In other portions of the county where the Chickamauga limestone is found many of the magnesian beds must be removed in order to procure the high-calcium stone. The limestones make a good lime for building and agricultural purposes, as well as for ballast, road metal, and concrete. The beds which are low in silica and alumina are suitable for fluxing purposes.

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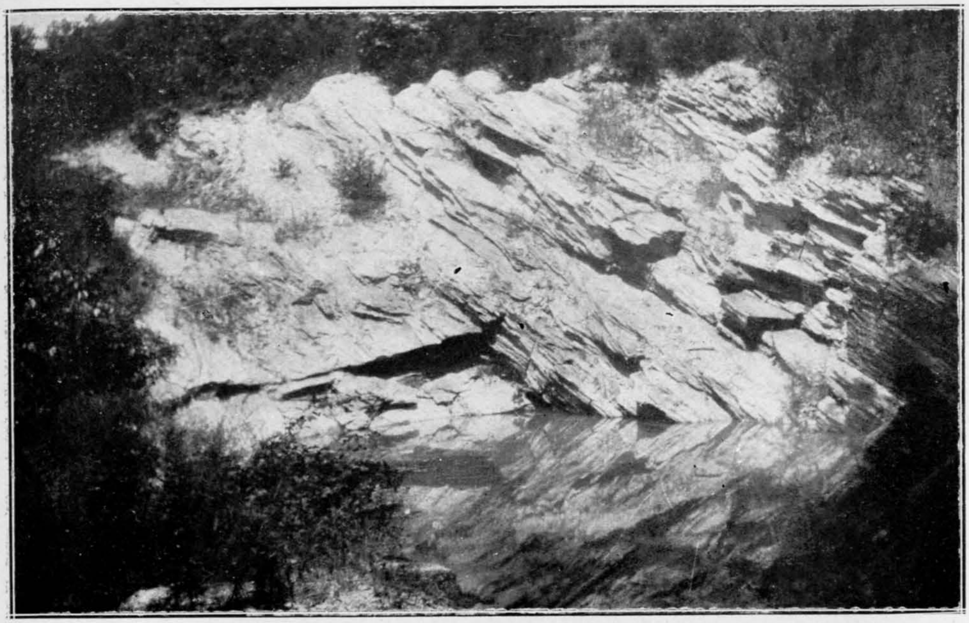
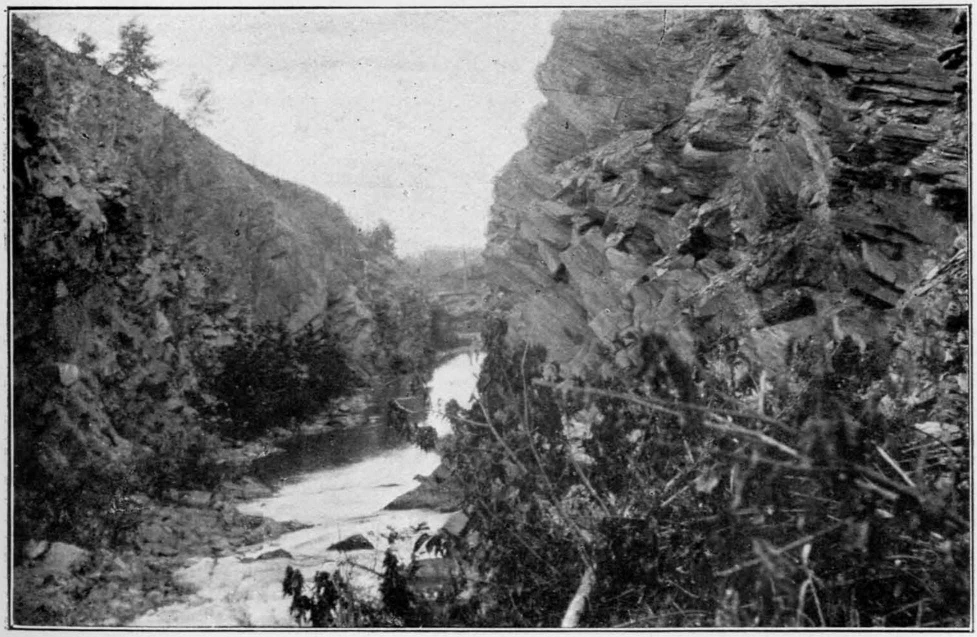
[1]Hayes, C. W., Rome folio (No. 78), Geol. Atlas U. S., U. S. Geol. Survey, 1902.



A. ROCKMART SLATES. QUARRY OF THE BLACK DIAMOND SLATE COMPANY, ABOUT 2 MILES NORTHEAST OF ROCKMART, POLK COUNTY, GEORGIA



B. ROCKMART SLATES. ARTIFICIAL CUT MADE BY SEABOARD RAILROAD IMMEDIATELY SOUTH OF ROCKMART, POLK COUNTY, GEORGIA

ROCKMART SHALES AND SLATES

The lower 1,600 feet of the Rockmart shales and slates consist largely of dark-blue to black shales and slates weathering often to olive-green or yellow and are remarkably uniform in lithologic character. The upper 1,000 feet consist of coarse limestone conglomerates at the base, succeeded by shales. In the upper portion of the formation beds of cherty limestone and sandy shales occur. The shales have been so changed by dynamic agencies that they have been metamorphosed into slates in the lower portion of the formation. These slates are well suited for mixing with a high-calcium lime in the manufacture of Portland cement.

DESCRIPTION OF INDIVIDUAL LOCALITIES

Marble Hill (Map location 1 P).—Marble Hill is situated in the town of Rockmart just south of the Southern Railway depot. The hill received its name from the fact that the limestone which occurs at this point was at one time thought to be marble. The remains of two lime kilns and two quarries on the south side of the hill show that this limestone was once quarried and burnt for commercial lime. The quarries are both situated in the upper gray magnesian beds of the Chickamauga limestone and are capped by the Rockmart shales and slates. The rocks strike N. 15° E., and dip 40° SE.

Section of Quarry, Marble Hill, Polk County

Sample No.	Unit No.	Description of Units	Thickness feet	Total Thickness feet
26	6	Heavy bedded, light blue limestone with some interstratified, heavy beds of gray limestone	57.8	290.1
	5	Concealed		
27	4	Dark blue, heavy-bedded limestone with some light-blue limestone interbedded	89.6	232.3
28	3	Dark-blue, heavy-bedded limestone becoming somewhat argillaceous at the top	52.4	142.7
29	2	Light-blue, heavy-bedded limestone, weathering to gray	63.1	90.3
29	1	Light, grayish-blue, heavy-bedded limestone	27.2	27.2

The following analyses show the character of the several beds of limestone in the above section:

Analyses of Limestone from Marble Hill

Sample No.	26	27	28	29
Unit No.	6	4	3	2&1
Lime (CaO)	44.64	43.58	51.56	35.86
Magnesia (MgO)	8.08	7.04	2.36	15.26
Ferric oxide (Fe_2O_3)	.90	.64	.66	.64
Silphur trioxide (SO_3)	.00	.00	.00	.00
Phosphorus pentoxide (P_2O_5)	.01	.02	.01	.00
Silica (SiO_2)	.97	1.47	1.24	2.50
Potash (K_2O)	.20	.20	.15	.15
Soda (Na_2O)	.08	.08	.15	.07
Clay bases	.67	1.29	.63	.92
Loss on ignition	44.45	45.68	43.24	44.60
	100.00	100.00	100.00	100.00

Ellis Davis and Son, slate quarry (Map location 2 P).—The slate quarry of Ellis Davis and Son is located in the southeastern portion of the town of Rockmart. The quarry is developed at the base of the Rockmart shales and slates, the underlying Chickamauga limestone being exposed. At its east end the quarry has a width of 160 feet in a general northeast-southwest direction, a length of 20 feet in a direction parallel to the strike of the rocks, and a height of 70 feet. These shales fulfill all the conditions for use in the manufacture of Portland cement. An average sample of the slates was taken over the entire quarry exposure, an analysis of which is given below.

Analysis of Slate from Ellis Davis and Son's Quarry

(Sample No. 30)

Moisture at 100° C.	.46
Loss on ignition	6.34
Lime (CaO)	.28
Magnesia (MgO)	2.60
Alumina (Al_2O_3)	20.80
Ferric oxide (Fe_2O_3)	4.93
Manganese (MnO)	.10
Potash (K_2O)	2.63
Soda (Na_2O)	1.40
Titanium dioxide (TiO_2)	.....
Silica (SiO_2)	59.74
	99.28

Rockmart Shale Brick and Slate Company (Map location 3 P).—The shale quarry of the Rockmart Shale Brick and Slate Company is situated immediately east of the brick plant in the town of Rockmart and at the base of the Rockmart shales and slates. The quarry is about 40 feet in width, several hundred feet in length, and between 10 and 30 feet in depth. The quarry can be developed both in a direction parallel to and across the strike of the rock. These shales are entirely suitable for use in the manufacture of Portland cement

An average sample of the whole quarry exposure was taken, an analysis of which is given below:

Analysis of Shale from Rockmart Shale Brick and Slate Company
(Sample No. 31)

Moisture at 100° C.	.30
Loss on ignition	5.20
Lime (CaO)	.10
Magnesia (MgO)	.40
Alumina (Al_2O_3)	19.79
Ferric oxide (Fe_2O_3)	3.91
Manganese (MnO)	.06
Potash (K_2O)	1.94
Soda (Na_2O)	1.23
Titanium dioxide (TiO_2)	.82
Silica (SiO_2)	66.32
	100.07

Morgan Hills (Map location 4 P).—The upper portion of the Chickamauga limestone is exposed in three separate hills about five miles southwest of Rockmart. The exposures occur just south of the road which parallels the southeast side of Uharlee Creek, on the property of G. W. Morgan, and extends from the creek level up the hillsides for about 50 feet. The limestones are heavy bedded and gray to light blue in color. Some thin shaly limestones occur in the upper portion of the formation and are overlain by crystalline, argillaceous rocks, which have been metamorphosed into phyllites.

The following analyses show the chemical composition of the limestone over the several exposures:

Analyses of Limestone from G. W. Morgan's Property

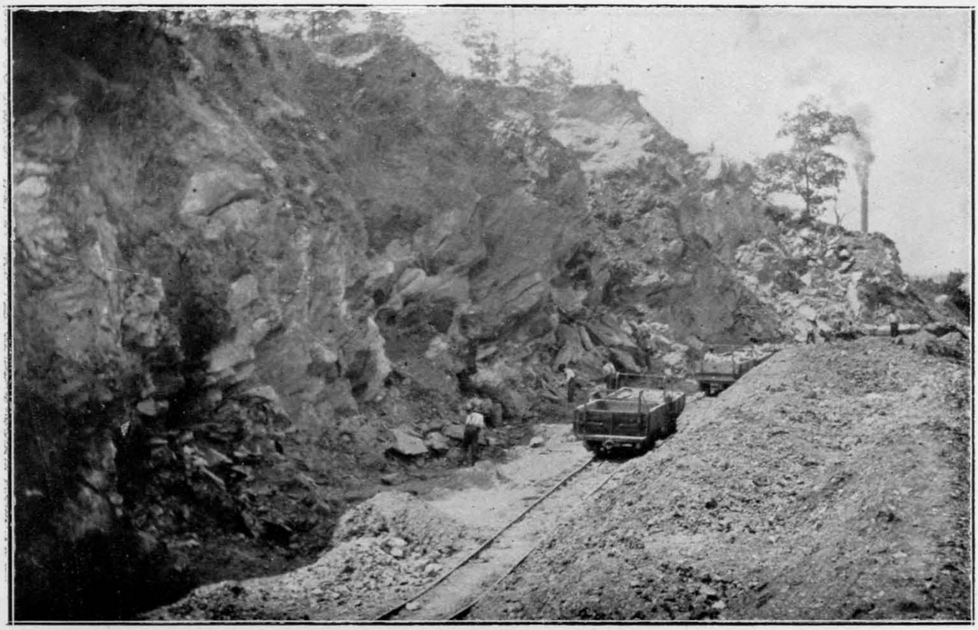
Sample No.	32	33	34
Map location	4P	4P	4P
Lime (CaO)	41.96	43.94	34.08
Magnesia (MgO)	6.62	6.52	15.80
Ferric oxide (Fe_2O_3)	.54	.54	1.20
Sulphur trioxide (SO_3)	.00	.00	.00
Phosphorus pentoxide (P_2O_3)	.02	.01	.01
Silica (SiO_2)	6.47	4.36	2.04
Potash K_2O)	.18	.18	.17
Soda (Na_2O)	.12	.12	.08
Clay bases	1.96	1.84	1.16
Loss on ignition	42.13	42.49	45.46
	100.00	100.00	100.00

Southern States Portland Cement Company (Map location 7 P.)—The plant of the Southern States Portland Cement Company is located about 1½ miles directly north of Rockmart, between the Southern and Seaboard railroads. This company was organized by H. F. Vandeventer in 1903, at that time secretary and treasurer of the Georgia Slate Company. The new company bought the property of the Georgia Slate Company with the intention of quarrying slate and using the waste material resulting from blasting, splitting, sawing, etc., in the manufacture of Portland cement.

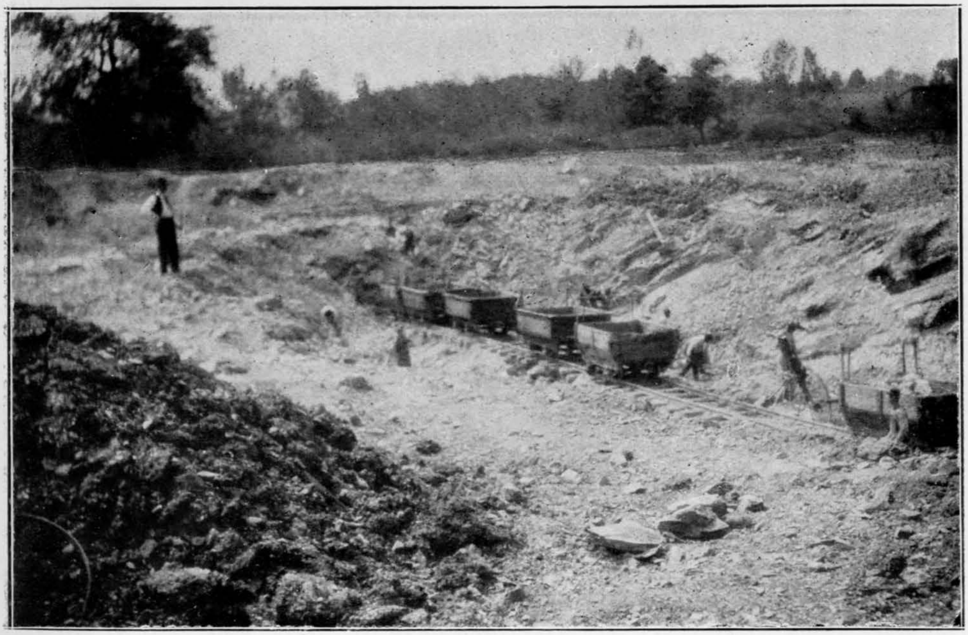
Subsequently, high-calcium limestones were found in the Chickamauga formation 1½ miles north of the town of Rockmart. The Rockmart shales were found to be of suitable composition at the same locality, so the idea of using the waste slate from the quarries of the Georgia Slate Company at Rockmart was abandoned and the plant was located on the property where the raw materials were found in juxtaposition.

The lithologic character of the Chickamauga limestones at this point can best be seen from the section given on a following page. The limestones used in the manufacture of cement occur in the upper portion of the formation.

The shales of the Rockmart formation immediately overly the Chickamauga limestones. The lower portion of the Rockmart forma-



A. CHICKAMAUGA LIMESTONE, QUARRY NO. 3, SOUTHERN STATES PORTLAND CEMENT COMPANY, ROCKMART, GEORGIA



B. CHICKAMAUGA LIMESTONE. A PORTION OF QUARRY NO. 1, SOUTHERN STATES PORTLAND CEMENT COMPANY, ROCKMART, GEORGIA tion only is exposed on this property. The shales at this point are apparently uniform in their lithologic character, dark blue to black in color, and weather often to yellowish-green and yellow.

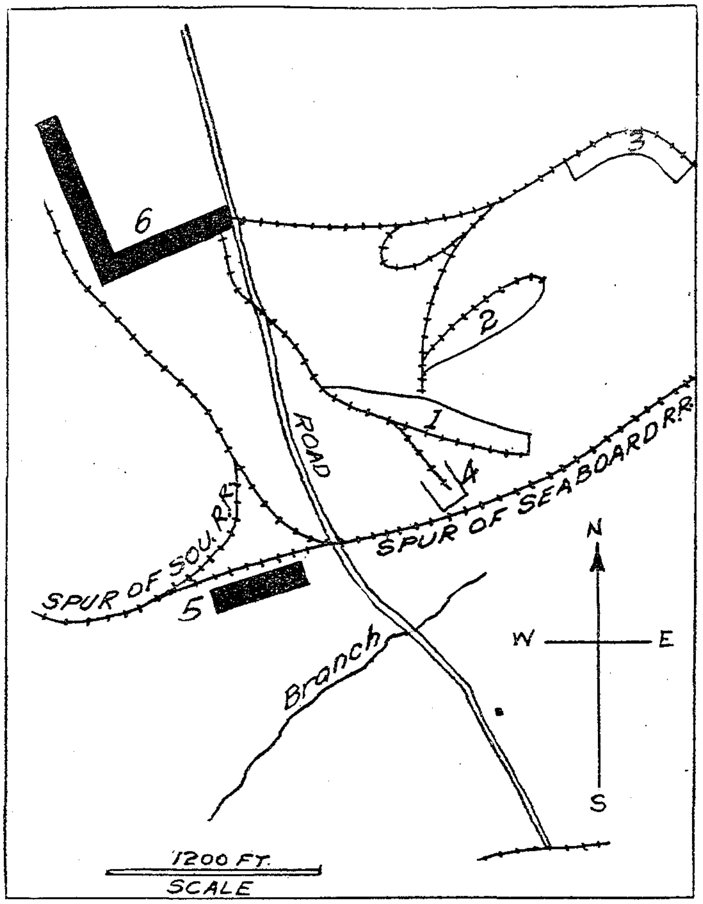


FIG. 4.—MAP SHOWING THE LOCATION OF MILL AND QUARRIES OF THE SOUTHERN STATES PORTLAND CEMENT COMPANY. (1) QUARRY NO. 1; (2) QUARRY NO. 2; (3) QUARRY NO. 3; (4) RECENT OPENING; (5) POWER HOUSE; (6) CEMENT MILL.

Close examination will show that some beds are extremely fine grained, with slick, greasy surfaces, while other beds are composed of somewhat hackly, siliceous shale. The unctuous shale carries considerable alumina and is not entirely suitable for use in the manufacture of Portland cement, while the rough looking, hackly shale is eminently satisfactory.

The following is an average analysis[1] of the rockmart shales for every two feet of stratigraphic thickness for a total of six feet above the Chickamauga limestone, showing the high content of alumina near the limestone, and the decrease of alumina and increase of silica as we proceed upward in the section:

	Feet	Silica	Alumina and iron oxide
Shale	2	71.70	20.02
Shale	2	56.12	36.40
Shale	2	49.40	39.64
Limestone.—			

The limestones are folded into small local anticlines and synclines. The bedding is thin to heavy, while the magnesian beds are usually heavy bedded to massive. The shales are characteristically fissile. The dip is both east and west, due to local folding, but the prevailing dip is to the east, varying from a small angle to 30° at the extreme east end of quarry No. 1. In quarry No. 2, the dip is as high as 50°. The strike is N. 22° E., in quarry No. 1, becoming almost due north in quarries No. 2 and No. 3.

CONDITIONS AFFECTING DEVELOPMENT

The limestone outcrops in the valley where the dip is gentle. To the east of the plant the limestone is exposed in a small hill due to a local fold. The shale occupies a higher position, topographically, than the limestone and caps this small hill. Quarries Nos. 1, 2, and 3 are all located along this hill, which runs in the same direction as the strike of the rock. The hill is about 875 feet long and about 250 feet wide at the base. The quarries were started some little distance above the general level of the valley and followed the strike of the rock. The drainage is natural and flows away from this hill in all directions, consequently no trouble is met in keeping the quarries dry.

There is in reality no overburden in these quarries, for the shale, which lies immediately above the limestone, is used in the manufacture of Portland cement. Some of the beds of shale are too low in silica

[1]Analysis made by Clarence N. Wiley, chief chemist, Southern States Portland Cement Company, 1909.

to be used alone, but when mixed with shales of other beds or with free silica they can be used satisfactorily.

The quantity of limestone available on this property outside of that in this hill can only be ascertained by drilling to determine its thickness and lithologic character below the general level of the valley.

The amount of shale suitable for use in the manufacture of Portland cement is in sufficient quantity to supply the plant almost indefinitely.

The fuel used is bituminous coal, which is secured from Tennessee. An average analysis[1] of coal used in the rotary kilns is as follows:

Analysis of Coal

Moisture	1.36
Volatile matter	28.24
Fixed carbon	61.38
Ash	9.02
	100.00
Sulphur	1.50

The following analyses[2] will show the chemical composition of the limestones and shales from the Southern States Portland Cement Company's quarries:

Analyses of Limestones and Shales, Southern States Portland Cement Company

	Limestones			Shales		
Sample No.	35	36	37	38	39	40
Lime (CaO)	53.04	52.67	53.96	4.85	.66	1.52
Magnesia (MgO)	2.02	.90	1.00	2.00	2.00	.80
Alumina (Al_2O_3)	.26	1.82		21.18	27.30	22.58
Ferric oxide (Fe_2O_3)	1.00		.94	3.77		3.94
Silica (SiO_2)	.52	3.10	1.24	57.35	62.60	60.10
Loss on ignition	42.86	41.62	42.64	7.10	5.90	6.60
	99.70	100.11	99.78	96.25	97.75	95.54

[1]Analysis by Clarence N. Wiley, formerly chief chemist, Southern States Portland Cement Company.

[2]Analyses by J. L. Mack, chemist, Southern States Portland Cement Company.

The following section of the Chickamauga limestone, exposed in quarry No. 1, gives a general idea of the character of the calcareous rocks at that point. The section begins at the easternmost exposure of the limestone at the contact of the Chickamauga limestone and the Rockmart shale.

Section, Quarry No. 1, Southern States Portland Cement Company

Unit No.	Description of Units	Thickness feet	Total Thickness feet
8	Dark-blue limestone (used in making cement)	32	120
7	Light-blue, heavy bedded and massive magnesian limestone. (Not used in making cement)	27.4	88
6	Dark-blue limestone, (used in making cement)	4	60.6
5	Heavy bedded and massive magnesian, bluish-gray limestone with veins of calcite and thin seams of dark-blue, high calcium lime, (only the dark blue, high-calcium lime used in making cement)	10.5	56.6
4	Dark-blue, apparently massive, somewhat argillaceous limestone, (used in making cement)	4.6	46.1
3	Light-gray, heavy-bedded, magnesian limestone, (not used in making cement)	6.0	41.5
	Center of local anticline		
2	Light and dark blue, massive limestone with a greenish cast; rather high in magnesia, but can be used in making cement by mixing with a limestone and shale running very low in magnesia	14.6	35.5
1	Light-blue limestone and interbedded gray limestone	20.9	20.9

At the base of this section the rocks dip to the west for a distance of 150 feet, and thence dip to the east.

Quarry No. 2 consists of the same strata as individual unit No. 8 in the section exposed in quarry No. 1, while in quarry No. 3 the total stratigraphic thickness (90 feet) of the dark blue limestone is available for use in the manufacture of cement. The limestone dips at an angle of 30° E., and is overlain by shale.

The following observations indicate an erosional unconformity between the Chickamauga limestone and the Rockmart shale at this point:

1. The shale does not dip at the same angle as the limestone.
2. A band of red clay in places separates the Chickamauga limestone from the Rockmart shales.
3. Limestone horses are overlain by stratified shale.

WINNING AND PREPARATION OF THE LIMESTONES

The limestone is first blasted from place by means of dynamite. The larger, more massive rock is then broken by means of sledge hammers into pieces convenient to be handled by the quarryman. It is loaded by hand on cars of a narrow gauge steam tram and carried to the stone house, where it is dumped by end tipple into a No. 7½ Gates gyratory crusher. The limestone is crushed to a size of two inches by three inches in diameter, and passes out of the crusher into a bucket elevator which carries the limestone above the crusher into a two-inch screen, allowing the two-inch and smaller material to pass through; the coarser material being returned to the crusher by means of a chute. The limestone passes from the two-inch screen to a belt conveyor which carries it to bins holding in reserve for the mill a 10 days capacity.

The limestone passes out of the bins on a belt conveyor into open rotary driers, two of which are used for the limestone. The driers are cylindrical in shape, about four feet in diameter ,and 40 feet in length. These driers have bolted on the interior Z-irons which act as shelves, carrying the rock to the top of the drier as the cylinder rotates, exposing it to the hot gasses emanating from the burning coal at the end of the drier. Most any coal can be used for this purpose and only a comparatively small quantity of heat is required to dry the limestone.

The limestone now passes out of the rotary driers into pan conveyors and from the pan conveyors to elevator buckets, thence to storage bins, which have a 10 hour capacity.

The limestone then passes to the ball mills. There are four ball mills for the preliminary grinding of the limestone, two Schmidt and two Krupp ball mills. The iron balls which are carried around on the interior of the drum fall from the top of the drum and literally pound the limestone into small particles, which pass through small openings into the screens surrounding the drum. The coarser material is separated from the finer material, the coarser being carried back to the interior of the drum while the finer passes on to another set of screens made of woven wire cloth and here again the finer material passes through into the dust proof casing, while the coarser material passes back again into interior of the drum, to be pounded fine enough to finally pass into the dust-proof casing. The ball mills are provided with hubs through which the limestone is fed into the drum and the hubs have feeders attached which regulate the amount of limestone passing into the ball mills.

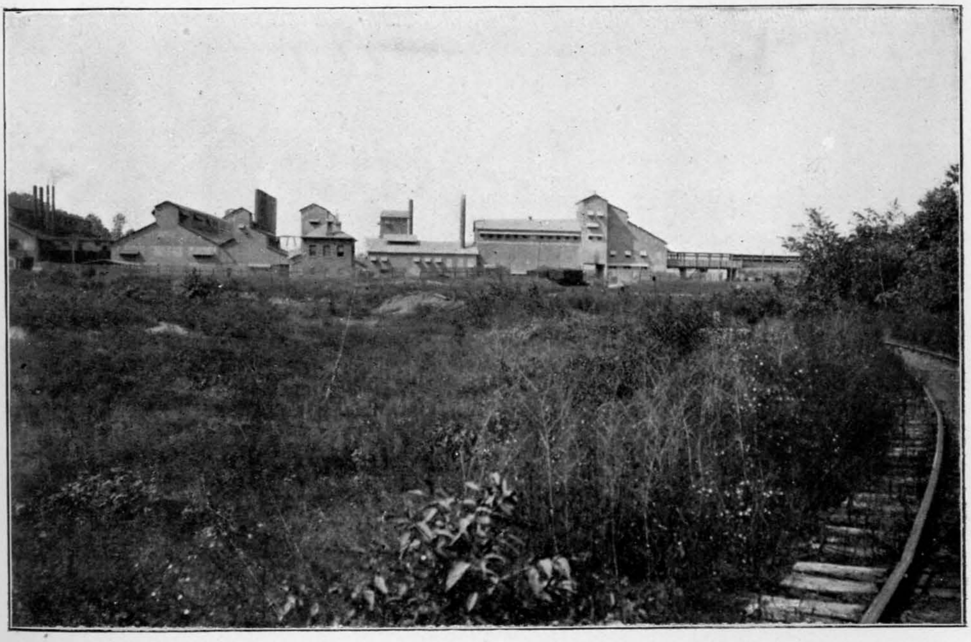
The finely ground limestone is conveyed from the ball mills by bucket elevators to bins, two of which hold the limestone. The limestone is now ready to be drawn from these bins to be weighed and mixed with the shale.

WINNING AND PREPARATION OF THE SHALE

The shales which are available for mixing with the limestone for the manufacture of Portland cement, are found in the same quarry as the limestone, overlying the limestone both stratigraphically and topographically. The shales which are easily procured by pick and shovel, are loaded on cars of narrow gauge steam tram and taken to the stone house. The shales are dumped from the cars by end tipple into a No. 3 Gates gyratory crusher. The shale passes from the crusher into a bucket elevator, thence to a twelve-inch screw conveyor, from which it is dumped into emergency storage bins.

The shale is carried from the storage bins by belt conveyors to bucket elevators which lift the shale to a closed rotary drier, one of which handles all the shale. The rotary drier is enclosed so that hot gasses circulate freely both on the inside and outside of the drier. More heat is required to dry the shales, as they carry more water than the limestone. The shale is carried from the drier by a bucket elevator into storage bins and is fed from the storage bins to the ball mill. One ball mill does all the necessary grinding of the shale. The shale is

A. CHICKAMAUGA LIMESTONE OVERLAIN UNCONFORMABLY BY ROCKMART SHALES AND SLATES, QUARRY NO. 3, SOUTHERN STATES PORTLAND CEMENT COMPANY, ROCKMART, POLK COUNTY, GEORGIA



B. MILL OF THE SOUTHERN STATES PORTLAND CEMENT COMPANY, ROCKMART, POLK COUNTY, GEORGIA elevated from the ball mill to storage bins and is now ready for mixing with the limestone.

MIXING LIMESTONE AND SHALE

At this point in the process the limestone is allowed to pass from the storage bins to the scales where one-half the limestone to be used is weighed. The scales are set mechanically and the amount of shale to be mixed with the limestone is weighed and dumped upon the limestone after which the remaining amount of the limestone necessary for the mix is weighed and dumped on the shale. This method of weighing aids the mixing of these two raw materials. The scales are kept locked, being set by the chemist who determines daily, or even more frequently, the amount by weight of the mix. The job of the weigher is purely a mechanical one.

From this point in the process of preparation of the raw materials the limestone and shale are treated as a unit. The mix of limestone and shale now passes from the weigh scales through a chute into a screw conveyor, which facilitates the mixing of these materials. The screw conveyor carries the raw materials to a rotary mixer, where the limestone and shale become intimately mixed. Elevator buckets carry the mix to bins which feed to a screw conveyor, carrying the raw materials into hoppers and then to the tube mills.

The plant has five tube mills, four Krupp and one Schmidt. The tube mills are cylindrical in shape, 20 to 22 feet long, and 60 to 66 inches in diameter and usually a little more than half filled with flint pebbles which are imported from Europe. The cylinder makes 28 revolutions a minute. The material passes into the cylinder through a hollow shaft and leaves the mill in the same way at the opposite end. There are numerous ways by which the feed is regulated. The Krupp mill is divided into compartments such that the material is forced to travel in a zig-zag motion. The flint pebbles pound the material in the tube mill to an impalpable powder. The impalpable powder is now ready for the kiln.

There are eight rotary kilns 6 feet by 60 feet with a capacity of 250 barrels each in 24 hours. The kilns make one revolution in 80 seconds, the regulation of the revolutions of the kilns regulating the output. Powdered coal is conveyed into the kiln through an injector into which air is forced by a fan. The main object is to carry the coal into the kiln and get a good mixture of powdered coal-dust and air, which is a very explosive mixture. The mixture in the kiln is thus raised to a very high temperature, so that the raw materials reach the point of incipient vitrification, and the clinker which forms passes out of the kiln into a McCaslin bucket conveyor and is carried to the clinker storage bins. The heat from the clinker is not utilized, but the clinker is allowed to cool and season in the storage clinker bins. The clinker remains in the bins at least two weeks and then is conveyed to the ball mills, where it is pounded to pieces, and as it passes through conveyors from the ball mills a small amount (2 per cent.) of gypsum is added. The ground clinker and gypsum now go to the tube mills. The product of the tube mills passes to the stock house where it is stored in 19 bins with 4,000 barrels capacity each. The finished product now passes from the bins by chutes to and through a screw conveyor, and is lifted by elevators to hoppers. It passes from hoppers into bins which lead to the Bates packing machines. The Bates packing machines feed the finished product into valve cotton sacks which hold 95 pounds of cement. The cement is usually packed in cotton sacks, but some is packed in paper bags and barrels.

The brand and trade name is "Southern States." The greatest capacity of the mill is 1,200 barrels per day.

Analysis of the "Southern States" Cement[1]

Lime (CaO)	61.82
Magnesia (MgO)	2.73
Alumina (Al_2O_3) / Ferric oxide (Fe_2O_3)	11.24
Sulphur trioxide (SO_3)	1.66
Silica (SiO_2)	21.21
Loss on ignition	1.21
	99.87

The following test[1] shows the physical character of the cement:

Physical Tests of "Southern States" Cement

Tensile strength	
Age	Neat
24 hrs.	493
7 days	829
28 days	973

Initial set	3 hrs. 10 min.
Final set	6 hrs. 5 min.
Fineness	
100	200
97.4	81.6
Boiling O. K.	

Piedmont Portland Cement Company (Map location 13 P).—The plant of the Piedmont Portland Cement Company is located at Portland, Polk County, directly on the Seaboard Air Line Railroad. The company was organized in the spring of 1909 with Dr. Edgar Everhart, of Atlanta, as President. The property was purchased from the Davitte Lime Company. In the fall of 1909, while the plant was under construction, Dr. Everhart resigned as President and was succeeded by J. C. Bass.

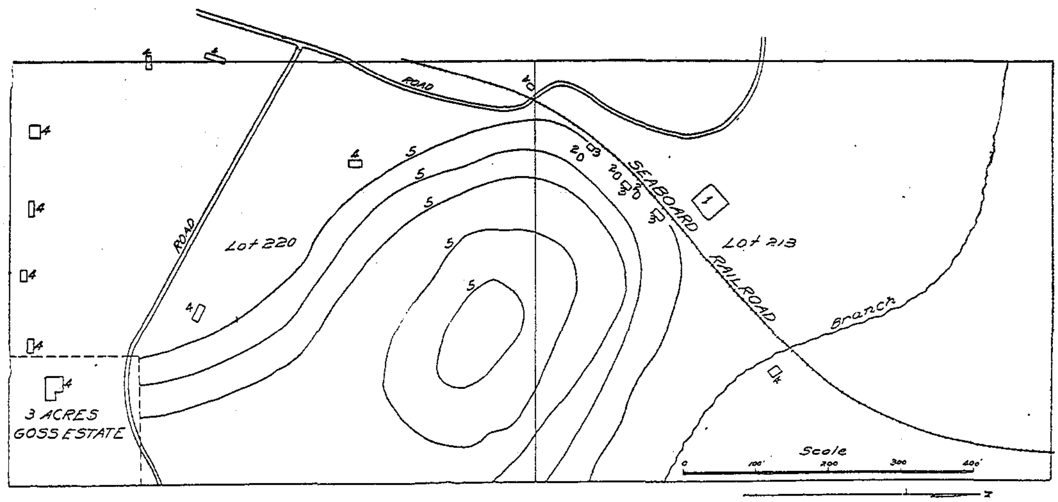


FIG. 5.—MAP SHOWING THE LOCATION OF THE PROPERTY, MILL AND QUARRY OF THE PIEDMONT PORTLAND CEMENT COMPANY, PORTLAND, GEORGIA. (1) CEMENT MILL; (2) LIME KILNS; (3) QUARRY; (4) HOUSES; (5) CONTOUR LINES.

GEOLOGIC RELATIONS

The raw materials used in the manufacture of Portland cement consist of the Chickamauga limestones and Rockmart shales and slates.

[1]Data furnished by Clarence N. Wiley, chief chemist, 1909.

The lithologic character of the limestone can best be seen from the section. It is not known just what the total thickness of the Chickamauga limestone is at this point, as the underlying Knox dolomite is not exposed in this vicinity; however, the lower heavy-bedded dark blue limestone of the Chickamauga formation is exposed and wherever exposures of the contact of the Chickamauga limestone and the underlying Knox dolomite are seen elsewhere the dolomite was found to lie only a few feet below these heavy beds. The Knox dolomite occurs at a comparatively short depth beneath the surface to the west of the plant, while to the east of the plant it would be found at some considerable depth, due to the dip of the rocks.

The shales of the Rockmart formation immediately overlie the Chickamauga limestone, and are only exposed in the lower portion of the formation. These shales are uniform in their lithologic character, dark blue to black in color, weathering to a yellowish-green and yellow and are entirely suitable for use in the manufacture of Portland cement. The rocks dip from 5 to 10 degrees southeast. The limestones are heavy bedded, while the shales are characteristically fissile.

The exposure at this point is on the eastern limb of a broad anticline, the dip of the rocks becoming steeper towards the east and flattening out to a small angle towards the crest of the anticline. The strike is N. 30° E.

CONDITIONS AFFECTING DEVELOPMENT

The limestone is exposed from the valley floor to a height of about 113 feet. From the section given below it is seen that units 1, 2, 3, 4, 5, 6, 8, 9 and 10 constituting 57.2 feet, or about 50 per cent. of the limestone, is entirely suitable for use in the manufacture of Portland cement. The upper units 11, 12 and 13 contain an average of 12 per cent. of magnesia; however, by the most careful separation of the dark blue high-calcium stone from the gray magnesian stone it is thought that probably 48 per cent. of this upper 51.7 feet may become available for cement manufacture. The shale lies immediately above the limestone and is present in more than sufficient quantity to supply the available limestone. The base of the quarry is on a level with the valley floor, so that as long as the quarry is worked above water level the drainage will be complete and there should be no trouble in keeping the quarry dry. The shale which overlies the limestone can not be considered as overburden as long as the quarrying of it precedes that of the underlying limestone with which it is used in the manufacture of cement. The quarry can be worked in a north and south direction for about 1,000 feet or more, while the length towards the east will depend on the removal of the overlying shale.

A high grade bituminous coal is used for burning the clinker. The coal used at this plant is known as the Straight Creek Kentucky coal. An average analysis of the coal used in the burning of the clinker is as follows:

Analysis of Coal

Moisture	3.20
Volatile matter	36.15
Fixed carbon	55.04
Ash	5.61
	100.00

Sulphur. No determination made.

CHEMICAL AND PHYSICAL PROPERTIES

The limestones used in the manufacture of Portland cement are dark-blue, fine-grained, crypto-crystalline, hard and compact. The shales are fine grained partly crystalline dark-blue and black or yellowish-green in color.

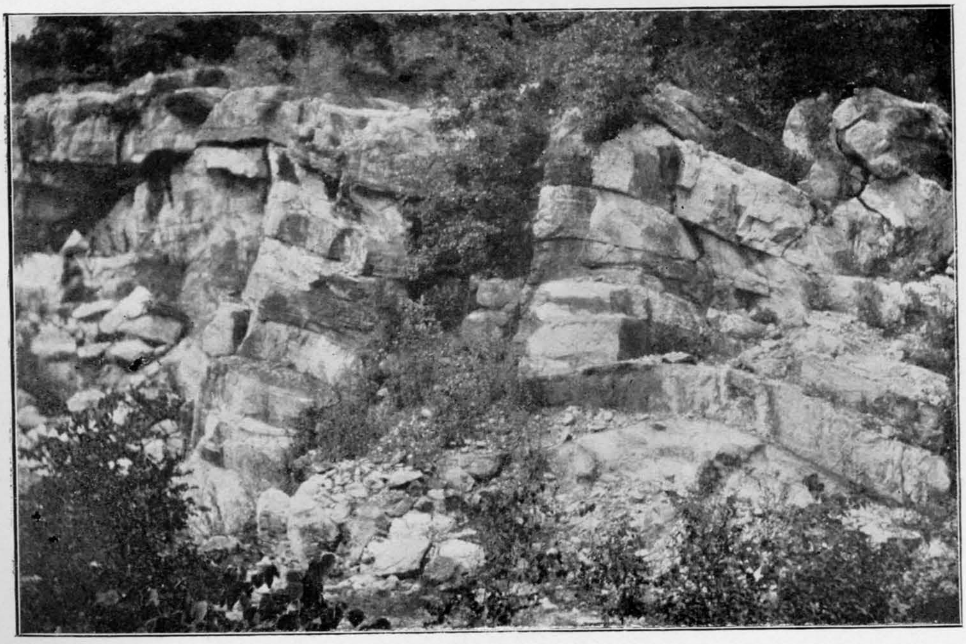
The following section begins at the lowest observed exposure of the Chickamauga limestone at a point about five feet above the level of the creek, just east of the cement plant and on the north side of the hill.

Section from Top to Bottom of Piedmont Portland Cement Company's Quarry

Sample No.	Unit No.	Description of Units	Thickness feet	Total Thickness feet
	14	Contact of the Rockmart shales and the Chickamauga limestone		
A	13	Light-blue and gray limestone interbedded	35.0	113.9
A	12	Light-blue limestone with calcite stringers	7	78.9
A	11	Bluish-gray to light-blue limestone with some thin beds of dark-blue limestone. The whole unit has a massive appearance	9.7	71.9
B	10	Massive dark-blue limestone	3	62.2
B	9	Bluish-gray limestone	3.5	59.2
B	8	Dark-blue limestone	1.1	55.7
C	7	Grayish-blue limestone weathering to a gray	5	54.6
D	6	Bluish-gray limestone weathering to a gray	5	49.6
D	5	Dark-blue limestone weathering to a dark gray	3.5	44.6
D	4	Dark-blue, fine-grained, somewhat massive limestone with some laminae of gray limestone	5	41.1
D	3	Dark-blue, fine-grained, somewhat massive limestone	7.7	36.1
D	2	Gray limestone	.4	28.4
E	1	Solid massive, dark-blue limestone, containing some few beds of shaly limestone	28.	28.0
		Valley level		.0

The following analyses show the chemical composition of the units described in the above section, together with an analysis of the Rockmart shale:

A. CHICKAMAUGA LIMESTONE, QUARRY OF THE PIEDMONT PORTLAND CEMENT COMPANY, PORTLAND, POLK COUNTY, GEORGIA



B. CHICKAMAUGA LIMESTONE, QUARRY OF THE BALD MOUNTAIN PORTLAND CEMENT COMPANY, 1¾ MILES NORTH OF ARAGON SPRINGS, POLK COUNTY, GEORGIA

Analyses of Limestones and Shales from Quarry of the Piedmont Portland Cement Company

Sample No. Unit No.	Shale	E 1	D 2–6	C 7	B 8–10	A 11–13
Lime (CaO)	.42	50.56	50.12	29.82	50.08	33.22
Magnesia (MgO)	2.30	2.08	1.81	14.10	2.32	12.68
Alumina (Al_2O_3)	21.38					
Ferric oxide (Fe_2O_3)	7.02	.32	.40	1.42	.50	.98
Sulphur trioxide (SO_3)		.00	.00	.08	.04	.64
Phos. pentoxide (P_2O_5)		.02	.01	.02	.01	.02
Silica (SiO_2)	59.26	3.00	3.36	11.78	2.70	8.98
Potash (K_2O)		.12	.17	.28	.16	.25
Soda (Na_2O)		.11	.14	.25	.18	.05
Clay bases		1.07	1.52	2.95	.98	1.62
Loss on ignition	6.19	42.72	42.47	39.30	43.03	41.46
	96.67	100.00	100.00	100.00	100.00	100.00

WINNING AND PREPARATION OF THE LIMESTONE

The limestone is drilled and blasted from place by means of steam drills and dynamite. The large, more massive rock is then broken by sledge hammers into pieces convenient to be handled by the quarryman. It is then loaded by hand into cars which are drawn by mules to the stone house where it is dumped into a No. 5 Kennedy gyratory crusher. The limestone is crushed to a size of two inches and under and is carried by elevator buckets to a storage bin with a capacity of 150 tons.

WINNING AND PREPARATION OF THE SHALE

The shale is easily quarried by means of pick and shovel and loaded into cars and drawn to the stone house by mules. The shale is dumped from the cars into a Jeffry hammer-ball disintegrater. The shale then passes by means of bucket elevators to a storage bin with a capacity of 100 tons.

MIXING LIMESTONE AND SHALE

The limestone and shale pass from the storage bins to the scales where they are weighed and mixed. From this point in the process of the manufacture of cement the limestone and shale are treated as a unit. On account of the fact that the limestone and shale are mixed before they are dried the moisture contained in them must always be taken into account. The mix now passes to an enclosed rotary drier which is heated by coal. After the material is thoroughly dried it passes to a bin with a capacity of 100 tons, situated immediately above the ball-tube mill into which it passes and is ground to a size of one-fourth inch and under. The mix passes from the ball-tube mill to a storage bin, which has a capacity of 100 tons, situated immediately above the two Fuller-Lehigh mills. The mix is ground by the Fuller-Lehigh mills to a fineness of 92 to 94 per cent. through a 100 mesh sieve and then passes to the kiln.

There is one rotary kiln 8 by 125 feet with a capacity of 500 barrels in twenty-four hours. The coal is crushed by a Fuller-Lehigh mill and dried and then conveyed to a bin in front of the kiln. The mix is burnt to incipient vitrification and passes out of the front end of the kiln as clinker. The clinker is carried by elevator buckets to a clinker cooler 6 by 60 feet. The gypsum is added after the clinker has been cooled and the final mix is passed through Chalmers and Williams 3-foot rolls, which crush the clinker to one-fourth inch and under. The crushed clinker is then conveyed to bins and carried from the bins to a Fuller-Lehigh mill where it is ground to a fineness of 90 per cent. through a twenty-mesh screen. The finely ground clinker now passes into an Allis Chalmers 6 by 22-foot tube mill where it is finally ground so that about 95 per cent. passes through a 100-mesh and about 80 to 84 per cent. through a 200-mesh sieve. It is then weighed by Richardson automatic scales and sacked.

The brand and trade name is "Piedmont," and the analysis is as follows:

Analysis[1] of the "Piedmont" Cement

Lime (CaO)	60.93
Magnesia (MgO)	3.72
Alumina (Al_2O_3) / Ferric oxide (Fe_2O_3)	9.94
Sulphur trioxide (SO_3)	1.31
Silica (SiO_2)	23.92
Loss on ignition	1.07
	100.89

[1]Analysis furnished by Mr. W. S. Davis, Supt.

Physical Tests[1] *of "Piedmont" Cement*

Tensile strength

Age	Neat	Sand
24 hrs.	460	
7 days	700	325
28 days	850	515

Initial set 1 hr. 45 min.
Final set 5 to 6 hrs.
Fineness

100	200
95	80-84

Boiling O. K.

Georgia Portland Cement and Slate Company (Map location 8 P). —The property of the Georgia Portland Cement and Slate Company is situated on the main road between Rockmart and Cartersville about 4 miles northeast of Rockmart, 1¾ miles distant from the Seaboard Railroad, and 2½ miles from the Southern Railway.

The raw materials are found in the immediate vicinity of Hayes mill and to the south on three contiguous lots, known as the Hayes, Wilson, and Scott lots respectively.

GEOLOGIC RELATIONS

The raw materials consist of the Chickamauga limestone and the Rockmart shales and slates. The limestone is grayish-blue to gray and heavy bedded, with some thin and heavy beds of a dark blue limestone interstratified. The limestone is somewhat argillaceous at the top and

Section of Georgia Portland Cement and Slate Company

Sample No.	Unit No.	Description of Units	Thickness feet	Total Thickness feet
		Rockmart shale.		
43	7	Bluish-gray, somewhat shaly limestone with some dark blue limestone	21	74.9
44	6	Gray limestone, massive and heavy-bedded	28	53.9
45	5	Bluish-gray limestone with some thin beds of blue limestone—dark beds at the bottom	13.6	25.9
	4	Gray, heavy-bedded limestone	2.8	12.3
	3	Gray, massive limestone	6	9.5
46	2	Dark-blue limestone	1.5	3.5
47	1	Gray limestone with occasional calcite stringers	2	2

[1]Data furnished by W. S. Davis, Supt.

the content of lime is highest in the upper 21 feet of the exposure.

The shales are in the lower portion of the Rockmart formation. They satisfy all the conditions for use as a mix with a high-calcium limestone in the manufacture of Portland cement. The rocks strike N. 25° E, and dip from 25° to 45° SE.

The section exposed on the east side of the Rockmart-Cartersville road, from top to bottom, is given above.

The following analyses show the chemical contents of the units above described:

Analyses of Limestone and Shale from Georgia Portland Cement and Slate Company

Sample No.	43	44	45	46	47	48
Unit No.	7	6	5,4,3	2	1	Shale
Lime (CaO)	50.12	43.40	36.68	55.20	35.76	.32
Magnesia (MgO)	2.28	7.54	12.94	.46	13.48	2.08
Alumina (Al_2O_3)	--------	--------	--------	.50	--------	18.97
Ferric oxide (Fe_2O_3)	.80	1.12	1.08	.20	1.50	5.85
Potash (K_2O)	.20	.19	--------	tr.	.22	3.80
Soda (Na_2O)	.07	.06	--------	tr.	.06	.40
Phos. pentoxide (P_2O_5)	.02	.02	tr.	.00	tr.	--------
Silphur trioxide (SO_3)	.00	.00	tr	.00	tr.	--------
Titanium dioxide (TiO_2)	--------	--------	--------	--------	--------	.92
Clay bases	1.75	2.15	1.51	.25	1.85	--------
Moisture at 100° C.	--------	--------	--------	--------	--------	.47
Loss on ignition	41.41	42.98	43.70	43.39	44.37	4.10
Silica (SiO_2)	3.35	2.54	4.09	--------	2.76	63.22
	100.00	100.00	100.00	100.00	100.00	100.13

CONDITIONS AFFECTING DEVELOPMENT

The limestone outcrops at the general level of the valley and extends up the hill, covering a stratigraphic thickness of about 75 feet. The shale lies immediately above the limestone and as it is used with the limestone in the manufacture of Portland cement it can not be considered as overburden, as long as the quarrying of it precedes that of the limestone.

From the accompanying section it will be observed that only the light blue and dark blue limestones are of suitable composition for use in the manufacture of Portland cement. The gray magnesian limestone will have to be quarried to obtain the interstratified dark blue and light blue high-calcium stone. The gray limestone can be utilized for ballast, road building, the burning of lime, and some portions are satisfactory for fluxing purposes. The property has not yet been developed.

Southern Lime Manufacturing Company (Map location 10 P).—The property of the Southern Lime Manufacturing Company is located about one-half mile east of Aragon station on the Seaboard railroad.

GEOLOGIC RELATIONS

The raw material used in the manufacture of lime at this point is the Chickamauga limestone and the whole exposure from top of the

Section of Quarry, Southern Lime Manufacturing Company

Sample No.	Unit No.	Description of Units	Thickness feet	Total Thickness feet
49	13	Grayish-blue, heavy-bedded limestone	25	71.4
	12	Grayish-blue and dark-blue heavy-bedded limestone	6.8	46.4
50	11	Dark-blue limestone with some lenses of gray limestone	3.6	39.6
	10	Dark-blue limestone	3	36
51	9	Massive, grayish-blue limestone with calcite seams	7	33
52	8	Dark-blue limestone with thin lenses of gray limestone	2.3	26
	7	Bluish-gray limestone with calcite stringers	2	23.7
	6	Dark-blue limestone with thin layers of gray limestone	2	21.7
53	5	Light bluish-gray, heavy-bedded limestone	3	19.7
54	4	Dark-blue limestone with thin gray limestone	4.6	16.7
55	3	Heavy-bedded, grayish-blue limestone with calcite	6.3	12.1
56	2	Dark-blue limestone with thin lenses of gray limestone	2	5.8
	1	Dark-blue, heavy-bedded limestone	3.8	3.8
		Base of exposure	0.0	0.0

hill to the valley level is quarried and burnt for lime. The limestone is both thin and heavy-bedded with the heavy beds predominating. The dip of the strata is only a few degrees to the east.

The above section from top to bottom of the exposure shows the physical character of the limestone at this point:

The following analyses show the chemical composition of the units described in the above section:

Analyses of Limestone, Southern Lime Manufacturing Company

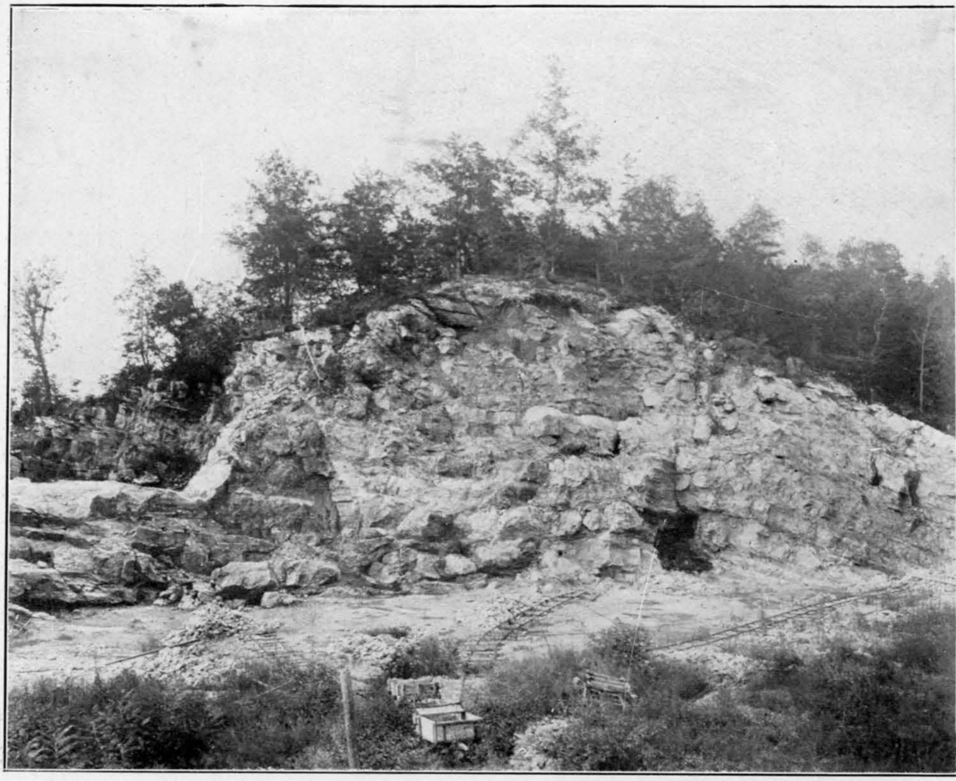
Sample No.	49	50	51	52	53	54	55	56
Unit No.	12,13	9	10,11	6,7,8	5	4	3	1,2
Lime (CaO)	41.96	50.88	35.46	48.18	36.16	50.48	30.60	51.88
Magnesia (MgO)	10.24	1.88	14.74	3.70	12.98	2.14	14.92	1.12
Ferric oxide (Fe_2O_3)	.72	.52	1.24	.64	2.00	.58	1.60	.32
Sul. trioxide (SO_3)	.00	.00	.27	tr.	.46	.00	tr.	.00
Phos. pentoxide (P_2O_5)	.01	.02	.02	.01	.02	tr.	.02	tr.
Silica (SiO_2)	1.11	1.96	2.65	2.52	2.18	4.13	9.76	3.59
Potash (K_2O)	.14	.24	.30	.24	.21	.20	.32	.15
Soda (Na_2O)	.20	.15	.20	.17	.15	.14	.17	.12
Clay bases	.71	1.50	.84	1.01	1.03	.77	1.56	.71
Loss on ignition	44.91	42.85	44.28	43.53	44.81	41.56	41.05	42.11
	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

CONDITIONS AFFECTING DEVELOPMENT

The limestone is exposed over a stratigraphic thickness of about 71 feet. The quarrying has been done above the general level of the valley, so that the drainage is natural and the quarries are always dry. The limestone extends from the top of the hill to the bottom, and there is very little overburden of residual material. The property is made accessible by its location on the Seaboard railroad. A low grade steam coal, which is secured from Tennessee, is used to fire the kilns.

SUGGESTIONS IN DEVELOPMENT

The limestone, when used in the manufacture of lime, should be hand-picked in the quarry after it is blasted from place. The dark blue, high-calcium limestone and the gray somewhat magnesian limestone should be loaded on separate cars and taken to separate kilns.



A. CHICKAMAUGA LIMESTONE, QUARRY OF THE SOUTHERN LIME MANUFACTURING COMPANY, ARAGON, POLK COUNTY, GEORGIA

B. ROCKMART SLATES. QUARRY OF ELLIS DAVIS' SONS, ROCKMART, POLK COUNTY, GEORGIA, SHOWING CLEAVAGE. BEDDING NOT SHOWN

On account of the fact that these two varieties of limestone can be easily distinguished by their color it is a simple matter for the quarryman to separate them in loading. If the high-calcium, dark blue limestone and the gray magnesian limestone are mixed heterogeneously and dumped into the kiln they do not burn at the same temperature, and the final product is not uniformly burnt. The high-calcium lime will slake rapidly on the addition of water, while the magnesian lime slakes slowly and consequently the lime will not slake thoroughly.

These difficulties can be overcome by burning the high-calcium lime and the magnesian lime in separate kilns.

DEVELOPMENT

The limestone is worked in open quarry. Operations began here about the year 1900. The stone is blasted from place by means of dynamite, and is then loaded on cars and drawn by pulley to the top of the incline and dumped into the kilns. There are two vertical kilns with separate feed, so the limestone does not come into contact with the fuel. The capacity is about 125 barrels per kiln in 24 hours. The lime is shipped in barrels and in bulk. If the limestone of different chemical composition is burnt in separate kilns a high grade lime for building and agricultural purposes could be obtained.

Three-fourths mile northeast of Red Ore (Map location 9 P).—The heavy-bedded limestones of the Chickamauga formation are exposed over 50 stratigraphic feet at a point about three-fourths mile northeast of Red Ore. The exposure occurs along the northeast side of a second-class public road which connects the Rockmart-Cartersville and the Rockmart-Aragon roads.

The following section from top to bottom of the exposure shows the physical character of the limestone:

Section Three-Fourths Mile Northeast of Red Ore

Sample No.	Unit No.	Description of Units	Thickness feet	Total Thickness feet
57	2	Blue, somewhat shaly, limestone at the top, becoming gray toward the bottom	35	45
58	1	Dark-blue, heavy-bedded limestone	10	10

The following analyses will show the chemical composition of the individual beds described in the above section:

Analyses of Limestone Three-Fourths Mile Northeast of Red Ore

Sample No.	57	58
Unit No.	2	1
Lime (CaO)	40.34	50.86
Magnesia (MgO)	10.36	3.14
Ferric oxide (Fe_2O_3)	1.00	.16
Sulphur trioxide (SO_3)	.00	.00
Phosphorus pentoxide (P_2O_3)	.01	tr.
Silica (SiO_2)	2.84	1.15
Potash (K_2O)	.16	tr.
Soda (Na_2O)	.08	tr.
Clay bases	1.08	.34
Loss on ignition	44.13	44.35
	100.00	100.00

Aragon Station, Seaboard railroad (Map location 11 P).—Limestones of the Chickamauga formation are exposed along the west side of the Seaboard railroad, about 1,000 feet north of Aragon Station. The limestones are heavy-bedded, dark to light-blue, and occur over an exposure of 15 stratigraphic feet.

The following analysis shows the chemical composition of the exposure:

Analysis of Limestone Near Aragon Station

(Sample No. 59)

Lime (CaO)	52.00
Magnesia (MgO)	1.16
Ferric oxide (Fe_2O_3)	.48
Sulphur trioxide (SO_3)	.22
Phosphorus pentoxide (P_2O_5)	.02
Silica (SiO_2)	2.70
Potassium (K_2O)	.12
Sodium (Na_2O)	.18
Clay bases	1.21
Loss on ignition	41.91
	100.00

Aragon Springs (Map location 12 P).—The limestone of the

Chickamauga formation is exposed for a few stratigraphic feet on the west side of the Aragon Springs-Rockmart road in the vicinity of the springs. The beds of limestone dip at a low angle in this valley, which structurally consists of a broad anticline.

The following analysis shows the composition of the entire exposure:

Analysis of Limestone at Aragon Springs
(Sample No. 60)

Lime (CaO)	48.96
Magnesia (MgO)	1.66
Ferric oxide (Fe_2O_3)	.80
Sulphur trioxide (SO_3)	.00
Phosphorus pentoxide (P_2O_5)	.02
Silica (SiO_2)	7.45
Potash (K_2O)	.34
Soda (Na_2O)	.08
Clay bases	1.09
Loss on ignition	39.60
	100.00

Davitte property (Map location 14 P).—The limestones of the Chickamauga formation are exposed along the road leading from Aragon mills north into Bartow County at a point about three-fourths mile south of the Bartow County line. The exposure is on the west

Section on J. Davitte Property

Sample No.	Unit No.	Description of Units	Thickness feet	Total Thickness feet
		Rockmart Shales		
61	4	Heavy-bedded, light-blue limestone becoming a gray-blue in the lower 20 feet	60	125
62	3	Light-blue limestone with some interbedded, somewhat shaly, light-blue limestone	20	65
63	2	Dark-blue limestone with interbedded, massive gray limestone	30	45
		Level of road		
64	1	Massive, dark-blue limestone	15	15
		Euharlee Creek		

side of Euharlee Creek and on the property of J. Davitte. The limestone is heavy-bedded and dips at a low angle to the southeast. The hill is capped by the Rockmart shales and slates.

The above section is not a continuous exposure, but is made up of a number of disconnected exposures which constitute a complete section:

The following analyses show the chemical composition of the individual beds described in the above section:

Analyses of Limestone from Davitte Property

Sample No.	61	62	63	64
Unit No.	4	3	2	1
Lime (CaO)	36.34	43.08	40.52	48.68
Magnesia (MgO)	12.92	5.48	9.14	3.30
Ferric oxide (Fe_2O_3)	.88	.48	.72	1.09
Sulphur trioxide (SO_3)	.00	.00	.00	.00
Phosphorus pentoxide (P_2O_5)	.02	.01	.01	.02
Silica (SiO_2)	4.30	5.77	3.88	2.93
Potash (K_2O)	.20	.20	.18	.10
Soda (Na_2O)	.14	.10	.16	.08
Clay bases	.82	1.47	.69	.41
Loss on ignition	44.38	43.41	44.70	43.39
	100.00	100.00	100.00	100.00

Bald Mountain Portland Cement Company (Map location 15 P).—The property of the Bald Mountain Portland Cement Company consists of about 300 acres located about 1¼ miles north of Aragon Springs, and about 2,000 feet east of the main public road which leads to the north.

The mountain consists of limestones of the Chickamauga formation above which stratigraphically occur the Rockmart shales and slates. The Chickamauga formation at this point consists of heavy-bedded, dark blue and gray high-calcium limestone and light blue limestone interstratified. On the south end of the property the limestone is exposed over a stratigrahpic thickness of 47 feet.

Section of Bald Mountain

Sample No.	Unit No.	Description of Units	Thickness feet	Total Thickness feet
65	2	Interbedded, dark-blue and light-blue limestone	40	47
66	1	Heavy-bedded, dark-blue, high-calcium limestone	7	7

On the west side of the hill the limestone is exposed for a considerable distance parallel to the strike. Sample No. 67 was taken as an average sample over the entire exposure on the west side of the hill.

The following analyses show the chemical composition of the individual beds described in the above section:

Analyses of Limestone from Bald Mountain

Sample No.	65	66	67
Unit No.	2	1	
Lime (CaO)	49.12	51.72	47.52
Magnesia (MgO)	3.52	1.52	4.71
Ferric oxide (Fe_2O_3)	.76	.58	1.24
Sulphur trioxide (SO_3)	.00	.00	tr.
Phosphorus pentoxide (P_2O_5)	.01	.01	.02
Silica (SiO_2)	3.88	3.59	3.90
Potash K_2O)	.20	.18	.20
Soda (Na_2O)	.05	.04	.12
Clay bases	.30	.34	.06
Loss on ignition	42.16	42.02	42.23
	100.00	100.00	100.00

Deaton's iron ore pit (Map location 16 P).—Deaton's iron ore pit is located about one mile east of Deaton Station on the Seaboard railroad. The pit occupies an irregular area on the side of a hill just above the level of the valley. The ore has been quarried to a depth of from 15 to 25 feet. Large horses of limestone occur throughout the pit. The limestone dips only a few degrees to the east and is exposed over a vertical and stratigraphic thickness of about 20 feet.

The following analysis shows the average chemical composition of the limestone over the entire exposure:

Analysis of Limestone from Deaton's Iron Ore Pit
(Sample No. 68)

Lime (CaO)	49.32
Magnesia (MgO)	2.56
Ferric oxide (Fe_2O_3)	.44
Sulphur trioxide (SO_3)	tr.
Phosphorus pentoxide (P_2O_5)	.02
Silica (SiO_2)	3.70
Potash (K_2O)	.17
Soda (Na_2O)	.20
Clay bases	.37
Loss on ignition	43.22
	100.00

Vicinity of Cedartown (Map location 6 P).—The Chickamauga limestone underlies the greater portion of the town and outcrops along the creek bottoms. There are many exposures of the limestone in this vicinity; however, it is never exposed for more than ten stratigraphic feet. The exposures are in the lower portion of the formation and consist of light blue to dark blue, heavy-bedded limestone. The dip is from 5 to 10 degrees east or west.

The following analysis shows the average chemical composition of the exposure at the intersection of Tanyard Branch with the main road leading from Cedartown to Youngs Station:

Analysis of Limestone Near Cedartown
(Sample No. 69)

Lime (CaO)	42.30
Magnesia (MgO)	7.66
Ferric oxide (Fe_2O_3)	.78
Sulphur trioxide (SO_3)	.03
Phosphorus pentoxide (P_2O_5)	.01
Silica (SiO_2)	4.99
Potash (K_2O)	.06
Soda (Na_2O)	.03
Clay bases	1.70
Loss on ignition	42.44
	100.00

Youngs Station (Map location 5 P).—Youngs Station is located on the Central of Georgia Railway about five miles southeast of Cedartown. At this point on the northeast side of the dam and opposite the old mill there is an exposure of the Knox dolomite which extends from the level of the creek to a height of about 12 feet. It consists of bluish-gray, fine-grained, partly crystalline dolomite with occasional layers of chert.

The following analysis shows the average chemical composition of the dolomite over the entire exposure:

Analysis of Limestone at Youngs Station

(Sample No. 70)

Lime (CaO)	28.72
Magnesia (MgO)	18.98
Ferric oxide (Fe_2O_3)	.68
Sulphur trioxide (SO_3)	tr.
Phosphorus pentoxide (P_2O_5)	.02
Silica (SiO_2)	4.12
Potash (K_2O)	.10
Soda (Na_2O)	.13
Clay bases	1.40
Loss on ignition	45.85
	100.00

FLOYD COUNTY

GEOLOGY

Beaver Limestone

The Beaver limestone in Floyd County is heavy bedded and massive, grayish-blue to light gray in color and semi-crystalline. The limestone occurs at only one locality in Floyd County, namely, at a point about 1½ miles southwest of Rome. The high percentage of magnesia in this limestone prevents its use in the manufacture of Portland cement and on account of the considerable residual material which overlies it the stone seldom outcrops where it can be commercially won for use as a flux or for the burning of lime.

Connasauga Shales and Limestones

The Connasauga formation in Floyd County consists of fine-grained, yellowish-green, argillaceous shales with many interbedded limestones. The thickness of the formation as estimated by Hayes[1] is 1,500 to 4,000 feet.

South of Rome the formation contains a large amount of limestone interbedded in olive clay shales. The limestones in the vicinity of Rome are so greatly metamorphosed that secondary calcite is intimately veined with the bluish-gray limestone. At a point southwest of Rome, on the Alabama division of the Southern Railway, about 1½ miles west of Agate, the limestone is dark blue to light blue, sometimes oölitic and frequently made up almost entirely of the remains of trilobites. In the vicinity of Cave Spring a section is exposed on Big Cedar Creek in Vans Valley. The lower portion of the formation contains some oölitic limestone, while the upper portion is a light-gray, dolomitic limestone. To the northeast of Rome the limestones are less abundant and occur as very thin beds interstratified with the shale, becoming prominent only at the top of the formation and about 1,000 feet below the top.

The Connasauga formation occupies a large area in the Coosa Valley, where it varies much in its lithologic character. The limestones in this broad area, locally known as "flat woods," are highly argillaceous and usually concealed.

The Connasauga limestone is at places a high-calcium stone, but the fact that high-calcium limestone beds are thin and interbedded and overlain by impure argillaceous and dolomitic limestone makes them unattractive for use in the manufacture of Portland cement. The oölitic beds in the lower portion of the formation are suitable for fluxing purposes. Some exposures occur where the limestone has not been fractured and the fissure subsequently filled with calcite and argillaceous impurities. At these localities the limestone is suitable for lime. The stone ought to prove valuable as a road material.

The silica-alumina ratio in the shales of this formation is low, so that unless free silica is added they cannot be used in the manufacture of Portland cement.

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[1]Hayes, C. W., Rome folio (No. 78), Geol. Atlas U. S., U. S. Geol. Survey, 1902.

Knox Dolomite

The Knox dolomite consists of heavy-bedded to massive gray dolomite, containing some dark almost black beds in both the lower and upper portion of the formation. The dark color is due to carbonaceous matter. A large amount of chert occurs in the upper portion of the formation.

This formation occupies almost the entire southeast portion of Floyd County, as well as considerable areas in the western and other portions of the county.

The high percentage of magnesia prevents the use of these rocks in the manufacture of Portland cement. On account of the extensive occurrence of chert in the upper portion of the formation it is difficult to locate quarries where the stone can be won for the manufacture of lime. The chert of this formation has been used largely as a road material.

Chickamauga Formation

Two phases of the Chickamauga formation are present in Floyd County. In the extreme southeast portion of the county there is a very small area, consisting of the lower portion of this formation, made up essentially of limestone. The dark-blue beds of high-calcium stone, which are equivalent to these beds, are used in the manufacture of Portland cement in Polk County. There are no exposures of this phase of the formation of economic importance in Floyd County.

Another phase of this formation is found in Horseleg Mountain; on the west side of Heath Mountain; another area in the vicinity of Sprite; and still another small area on the west side of John Mountain, which extends north into Chattooga County.

This phase of the Chickamauga formation consists largely of varicolored, argillaceous shales with interbedded, mottled, earthy limestones. The limestones are gray in the lower portion of the formation with pinkish limestones above and below; however, the argillaceous limestones of a light blue color, interbedded with the shales, usually predominate. A conglomerate occurs near the base of the formation which consists of pebbles of chert derived from the Knox dolomite and deposited while the latter formation was being eroded to the east. These chert fragments are imbedded in a calcareous-argillaceous matrix. The thickness of the formation varies from 200 to 1,500 feet.

The limestones and shales of the Chickamauga formation dip beneath the overlying Rockwood formation. The lower portion of the Rockwood formation carries a heavy-bedded, flaggy sandstone. The weathered detritus from this sandstone conceals a large portion of the underlying rocks. The limestones of the Chickamauga formation are thin-bedded and as they contain numerous interstratified shales and vary in their lithologic character over short distances with a usually heavy overburden, they do not possess attractive possibilities for the economic production of Portland cement, or for lime. They can, however, be used to an advantage, when crushed, for road material.

Floyd Formation

The Floyd formation consists mostly of dark-blue to black carbnaceous shales with some yellow and brown-colored shales and dark-blue calcareous shales. Some sandy beds are found, and near the middle of the formation occur heavy-bedded, dark-blue to light-blue and gray crinoidal limestone. The thickness of the formation varies between 1,500 and 2,200 feet. The limestones are not prominent in the vicinity of Rome; however, the shales at this point are extremely calcareous. The limestones are more prominent to the west and northwest of Rome, and sometimes reach a thickness of 100 feet.

The Floyd formation contains the most important limestones in Floyd County. These limestones are often very pure, high-calcium stones, which are suitable, when found in sufficient quantity, for the manufacture of Portland cement. They are well adapted for the burning of lime, for building and agricultural purposes, for flux, and road material.

Sixteen samples of the Floyd limestone were taken in this county, eleven of which contained less than 1 per cent. of magnesia, while five contained more than 1 per cent., but less than 2 per cent. The Floyd limestone in this county is characterized by a very low percentage of magnesia. It contains some chert and some beds are high in silica.

The Floyd shales are not often physically uniform over any considerable stratigraphic extent. They sometimes contain laminae of limonite, and again they are extremely argillaceous. Some portions of the shale are very siliceous, and all of it is more or less carbonaceous. Certain portions of the formation will be found quite suitable for mixing with a high-calcium limestone in the manufacture of Portland cement.

Bangor Formation

The Bangor limestone occurs in only one portion of Floyd County, namely, at Rocky Mountain. The upper portion of the formation consists largely of shales (Pennington), while limestones occupy the lower portion of the formation. The thickness of the Bangor formation is not more than 350 feet. It is usually concealed by the detritus derived from the overlying sandstone of the Lookout formation. The limestone in this area is a very high-calcium stone and is characterized by a low percentage of magnesia. It is chemically suitable for use in the manufacture of Portland cement, for the manufacture of lime for commercial and agricultural purposes, and for crushed stone products.

DESCRIPTION OF INDIVIDUAL LOCALITIES

Haynie (Map location 1 F).—The grayish-blue limestone of the Connausauga formation is exposed over a thickness of not more than 20 feet at a point along the north side of the Cave Spring-Alabama road in the extreme southwest corner of Floyd County.

The following analysis shows the chemical composition of the limestone over the entire exposure.

Analysis of Limestone from Haynie Post Office

(Sample No. 71)

Lime (CaO)	47.60
Magnesia (MgO)	2.14
Ferric oxide (Fe_2O_3)	1.44
Sulphur trioxide (SO_3)	.00

Phosphorus pentoxide (P_2O_5)	tr.
Silica (SiO_2)	5.38
Potash (K_2O)	.20
Soda (Na_2O)	.10
Clay bases	2.47
Loss on ignition	40.67
	100.00

Henry Bass property (Map location 2 F).—The property of Henry Bass is located within the corporate limits of the city of Rome, 500 feet south of the Etowah bridge. Thin-bedded, grayish-blue limestone of the Connasauga formation is exposed from the river level to the top of the hill, which rises to a height of more than 100 feet above the river. The limestone contains numerous veins of secondary calcite associated with visible impurities of iron and laminæ of argillaceous material.

The following analysis shows the average chemical composition of the limestone over the entire exposure:

Analysis of Limestone from Henry Bass Property
(Sample No. 72.)

Lime (CaO)	32.44
Magnesia (MgO)	11.62
Ferric oxide (Fe_2O_3)	4.36
Sulphur trioxide (SO_3)	.30
Phosphorus pentoxide (P_2O_5)	.02
Silica (SiO_2)	6.51
Potash (K_2O)	1.35
Soda (Na_2O)	.37
Clay bases	4.50
Loss on ignition	38.53
	100.00

Southwest Rome (Map location 3 F).—The limestones of the Connasauga formation are exposed at a point about 3,000 feet south of the Etowah River bridge just west of Rome. These dark-blue limestones are exposed over about 70 stratigraphic feet. They are somewhat argillaceous and intimately veined with secondary calcite. The composition is similar to the limestones described immediately above on the Bass property. The strike is N. 35° E., and the dip 45° SE.

Northeast Rome (Map location 4 F).—At a point 480 feet southwest of the Southern Railway culvert north of the W. & A. Railroad, a thin and somewhat heavy-bedded dark blue limestone of the Connasauga formation is exposed over 63 stratigraphic feet. The limestones contain a considerable number of laminæ of clayey impurities, and while secondary calcite occurs it is not quite so abundant as in the limestones southwest of Rome.

The following section shows the physical character of the exposure from top to bottom:

Section of Limestone Exposure Northeast of Rome

Sample No.	Unit No.	Description of Units	Thickness feet	Total Thickness feet
73	2	Dark-blue limestone with some interbedded, argillaceous shale	11.9	63.2
	1	Interstratified, thin and heavy beds of gray and dark-blue limestone, with considerable secondary calcite and intercalated clayey impurities.	51.3	51.3

The following analysis shows the composition of the units exposed:

Analyses of Limestone Northeast of Rome

Sample No.	73	74[1]
Unit No.	1 & 2	
Lime (CaO)	45.94	50.40
Magnesia (MgO)	1.00	2.05
Ferric oxide (Fe_2O_3)	2.68	1.04
Sulphur trioxide (SO_3)	tr.	.00
Phosphorus pentoxide (P_2O_5)	.00	.00
Silica (SiO_2)	6.32	2.35
Potash (K_2O)	--------	.12
Soda (Na_2O)	--------	.09
Clay bases	4.95	1.51
Loss on ignition	39.11	42.44
	100.00	100.00

[1]Number 74 was taken over the exposure of the limestone along the river bank beneath the section described above.

Six-Mile Station (Map location 5 F).—The limestone of the Connasauga formation is exposed for about ten stratigraphic feet at a point one mile west of Six-Mile Station along the south side of the Alabama division of the Southern Railway. The limestone outcrops in a low hill where it is overlain by shales of the same formation. The limestone is dark-blue in color, fine grained, and appears somewhat heavy bedded. Some earthy impurities are present which increase toward the top of the exposure.

The following analysis will show the average chemical composition of the limestone over the entire exposure:

Analysis of Limestone from Six-Mile Station

(Sample No. 75)

Lime (CaO)	47.00
Magnesia (MgO)	3.00
Ferric oxide (Fe_2O_3)	1.74
Sulphur trioxide (SO_3)	.10
Phosphorus pentoxide (P_2O_5)	.01
Silica (SiO_2)	3.63
Potash (K_2O)	.25
Soda (Na_2O)	.12
Clay bases	2.58
Loss on ignition	41.57
	100.00

Big Cedar Creek exposure (Map location 6 F).—The limestone of the Connasauga formation is exposed over a thickness of about 30 feet about one mile northwest of Vans Valley, along the north side of Big Cedar Creek. The lower ten feet of the exposure consists of light bluish-gray limestone, resembling in lithologic character the Knox dolomite, over which sample No. 76 was taken. Immediately above this unit lies ten feet of shaly limestone which in places might be termed a calcareous shale. Sample No. 77 was taken over this unit. At the top of the exposure the rock is a dolomitic limestone and is in all probability a part of the Knox dolomite. The cherty limestone was omitted in No. 78. The strike is N. 45° E., and the dip 15° SE.

The following analyses show the chemical composition of the limestone over the units described above:

Analyses of Limestone from Big Cedar Creek Exposure

	76	77	78
Lime (CaO)	15.40	14.18	48.30
Magnesia (MgO)	10.96	3.20	20.00
Ferric oxide (Fe_2O_3)	1.76	4.18	2.44
Sulphur trioxide (S_2O_3)	tr.	tr.	.00
Phosphorus pentoxide (P_2O_5)	.02	.04	.02
Silica (SiO_2)	30.24	31.95	1.97
Potash (K_2O)	3.41	4.48	.15
Soda (Na2O)	.31	.35	.06
Clay bases	10.73	12.68	.39
Loss on ignition	27.17	28.94	26.67
	100.00	100.00	100.00

Exposure near Pinson (Map location 7 F).—The somewhat heavy-bedded, dark-blue limestones of the lower portion of the Connasauga formation are exposed over a stratigraphic thickness of about 57 feet at a point about 850 feet east of Woodward Creek one-half mile west of Pinson. The limestones form a low ridge and are overlain by yellow and green shales of the same formation.

The following analyses show the chemical composition of the limestones and shales at this point:

Analyses of Limsetone and Shale Near Pinson

Sample No.	Limestone 79	Shale 80
Lime (CaO)	51.00	.31
Magnesia (MgO)	2.20	.40
Alumina (Al_2O_3)	----------	25.40
Ferric oxide (Fe_2O_3)	1.54	6.12
Sulphur trioxide (SO_3)	tr.	-------
Manganese (MnO)	----------	tr.
Titanium dioxide (TiO_2)	----------	tr.
Silica (SiO_2)	2.90	55.39
Loss on ignition	42.36	4.61
Moisture at 100° C	----------	1.50
	100.00	93.73

Exposure near Nannie (Map location 8 F).—The heavy-bedded, dark-blue limestones of the Connasauga formation are exposed from the valley floor to a vertical height of about 55 feet, about 1½ miles northeast of Nannie on the east side of the road which parallels Armstrong Mountain. The limestones carry numerous veins of secondary calcite in the lower portion of the exposure. Yellow and yellowish-green argillaceous shales overlie the limestones. At the top of the shale an exposure of the Connasauga-Knox contact can be seen.

The following analyses show the chemical character of the limestones and shales at this point:

Analyses of Limestone and Shale from Near Nannie

Sample No.	Shale 81	Limestone 82
Lime (CaO)	1.61	49.76
Magnesia (MgO)	2.14	.64
Alumina (Al_2O_3)	19.78	----------
Ferric oxide (FE_2O_3)	6.46	1.62
Sulphur trioxide (So_3)	--------	tr.
Phosphorus pentoxide (P_2O_5)	--------	----------
Silica (SiO_2)	57.35	6.73
Manganese (MnO)	.08	----------
Titanium dioxide (TiO_2)	.54	----------
Loss on ignition	5.40	41.25
Moisture at 100° C	1.46	----------
	94.82	100.00

Oostanaula River exposure (Map location 9 F).—The limestones of the Floyd formation are exposed over a stratigraphic thickness of about 80 feet at a point one-half mile north of Margie on the west side of the Oostanaula River east of Turkey Mountain. The limestone which is heavy-bedded and nearly horizontal, varies in color from dark-blue to light-blue.

The following analysis shows the average chemical composition of the limestone over the entire exposure at this point:

Analysis of Limestone from Oostanaula Creek
(Sample No. 83)

Lime (CaO)	53.20
Magnesia (MgO)	.52
Ferric oxide (Fe_2O_3)	.68
Sulphur trioxide (SO_3)	tr.
Phosphorus pentoxide (P_2O_5)	....
Silica (SiO_2)	2.71
Loss on ignition	42.89
	100.00

J. Scott Davis property, Vans Valley (Map location 10 F).—Occasional exposures of limestone occur on the property of J. Scott Davis along the west side of the hill to the northwest of the Davis residence. This limestone has been mapped by Hayes[1] as part of the Connasauga formation. The dolomitic character of the limestone, with the chert which it contains, however, suggests that it is a part of the Knox dolomite formation. The dolomite is partly crystalline, bluish-gray to light-gray in color and fairly uniform in its lithologic character. Chert nodules are most abundant in the upper portion of the exposure.

The following analysis shows the average chemical composition of the entire exposure:

Analysis of Limestone from J. Scott Davis Property
(Sample No. 84)

Lime (CaO)	29.24
Magnesia (MgO)	19.46
Ferric oxide (Fe_2O_3)	1.60
Sulphur trioxide (SO_3)	.00
Phosphorus pentoxide (P_2O_5)	tr.
Silica (SiO_2)	4.22
Potash (K_2O)	.16
Soda (Na_2O)	.08
Clay bases	.71
Loss on ignition	44.53
	100.00

West side of Lavender Mountain (Map location 11 F).—Some exposures of the limestone of the Chickamauga formation outcrop on the

[1]Hayes, C. W., Rome folio (No. 78), Geol. Atlas U. S., U. S. Geol. Survey, 1902.

west side of Lavender Mountain at a point one mile north of the Central of Georgia Railway and about 2,000 feet east of the valley public road between Sims and Lavender mountains. The limestones are thin bedded, grayish white, pink and light blue, semi-crystalline, and are interbedded in variegated shales. In the lower portion of the formation a conglomerate is exposed consisting of pebbles of chert imbedded in a limy clay matrix.

The following section of the limestone from the top to the bottom of the exposure shows its physical character:

Section on West Side of Lavender Mountain

Sample No.	Unit No.	Description of Units	Thickness feet	Total Thickness feet
85	5	Thin and heavy beds of pink and gray limestone interstratified	22	113
	4	Pinkish, massive limestone	11	91
86	3	Grayish-white, fine-grained limestone with much crystalline calcite, the cleavage faces of which give a bright silvery metallic lustre	23	80
	2	Concealed	57	57
	1	Conglomerate		

Above unit 5 of the section the rocks are largely concealed. Occasional outcroppings of shale were observed between unit 5 and the lower heavy-bedded sandstone of the Rockwood formation.

The following analyses show the chemical composition of the limestones:

Analyses of Limestone from West Side of Lavender Mountain

Sample No.	85	86
Unit No.	4&5	3
Lime (CaO)	47.28	54.64
Magnesia (MgO)	.60	.20
Ferric oxide (Fe_2O_3)	.96	.32
Sulphur trioxide (SO_3)	--------	.20
Phosphorus pentoxide (P_2O_5)	.03	tr.
Silica (SiO_2)	9.90	.90
Potash (K_2O)	.26	tr.
Soda (Na_2O)	.14	tr.
Clay bases	2.64	.41
Loss on ignition	38.19	43.33
	100.00	100.00

Beach Creek exposure (Map location 12 F).—The limestone of the Floyd formation is exposed on the south side of Beach Creek at its intersection with the road between Horseleg Mountain and Oreburg. These rocks consist of a dark-blue to light-blue crinoidal limestone quite uniform from top to bottom. There are no visible impurities in the limestones; however, they are capped by a thin layer of chert. The strike is north and south and the dip 15° W.

On the southwest side of the road the limestone is exposed over a thickness of 10 feet, a section of which is here given:

Section on Beach Creek

Sample No.	Unit No.	Description of Units	Thickness feet	Total Thickness feet
87	2	Grayish-blue, heavy-bedded limestone	4	10
88	1	Dark-blue heavy-bedded limestome	6	6

On the east side of the road at this point in the upper few feet of very cherty limestone sample, No. 89, was taken. Below the cherty limestone there is an exposure of about fifteen feet of heavy-bedded, high-calcium stone, from the average of which sample No. 90 was taken.

The following analyses show the chemical character of these limestones:

Analyses of Limestones from Beach Creek

Sample No. Unit No.	87 2	88 1	89	90
Lime (CaO)	53.40	53.48	44.76	52.44
Magnesia (Mgo)	.42	.84	.64	.74
Ferric oxide (Fe_2O_3)	.80	.26	.72	1.04
Sulpher trioxide (SO_3)	tr.	tr.	tr.	tr.
Phosphorus pentoxide (P_2O_5)	tr.	tr.	.01	tr.
Silica (SiO_2)	2.66	1.53	15.62	3.58
Potash (K_2O)	.07	.04	.10	.10
Soda (Na_2O)	.08	.05	.04	.11
Clay bases	.74	.64	.72	.83
Loss on ignition	41.83	43.16	37.39	41.16
	100.00	100.00	100.00	100.00

Lavender Station (Map location 13 F).—The dark-blue, high calcium limestones of the Floyd formation are exposed for only about 10 stratigraphic feet at a point about 100 feet southwest of Lavender Station on the property of Karr Berryhill.

The following analysis shows the average chemical composition of the whole exposure at this point:

Analysis of Limestone at Lavender Station
(Sample No. 91)

Lime (CaO)	54.72
Magnesia (MgO)	.80
Ferric oxide (Fe_2O_3)	.24
Sulphur trioxide (SO_3)	.00
Phosphorus pentoxide (P_2O_5)	.00
Silica (SiO_2)	.72
Potash (K_2O)	.09
Soda (Na_2O)	.07
Clay bases	.36
Loss on ignition	43.00
	100.00

Halls Mountain (Map location 14 F).—Halls Mountain is situated near the northwest corner of Floyd County only about one-fourth mile

Section from Top to Bottom on Halls Mountain

Sample No.	Unit No.	Description of Units	Thickness feet	Total Thickness feet
92	7	Argilaceous shalle with some thin beds of sandstone	30	92.1
93	6	Thin-bedded dark-blue limestone	17	62.1
94	5	Dark-blue arenaceous shale	6.5	45.1
95	4	Dark-blue limestone	5.6	38.6
96	3	Somewhat arenaceous limestone with many beds of shaly limestone	18	33
97	2	Heavy-bedded, dark-blue limestone	5	15
98	1	Dark-brown and black arenaceous shale	10	10

south of the Floyd-Chattooga County line and about two miles north of the North Rome and Attalla Railroad.

This mountain consists of shale at the base, above which occurs 60 feet of limestone capped by 30 feet of shale. The shale and limestone are in the upper half of the Floyd formation. The shales are carbonaceous and fissile, while the associated limestones are usually heavy-bedded, dark-blue to light-blue in color with some argillaceous and arenaceous beds. The whole exposure is characterized by a very low percentage of magnesia. The rocks strike N. 50° W., and dip 5° SE.

The following analyses show the chemical character of the units described in the above section:

Analyses of Limestone from Halls Mountain

Sample No.	92	93	94	95	96	97	98
Unit No.	7	6	5	4	3	2	1
Lime (CaO)	12.36	41.56	21.42	48.26	46.52	52.36	5.04
Magnesia (MgO)	.54	1.00	.18	1.82	.46	.00	.27
Ferric oxide (Fe_2O_3)	3.40	2.40	3.76	1.22	2.72	1.56	5.04
Sulphur trioxide (SO_3)	.20	.10	.04	------	.00	.00	.00
Phos. pentoxide (P_2O_5)	------	.00	.00	.01	.02	.00	.02
Silica (SiO_2)	62.78	16.69	39.12	7.00	9.04	1.11	63.18
Potash (K_2O)	1.02	.23	1.60	.14	.24	.09	------
Soda (Na_2O)	.42	.25	.72	.12	.20	.07	------
Clay bases	7.50	2.68	12.34	1.33	2.92	.87	17.50
Undertermined	11.78	35.09	20.82	40.10	37.88	43.94	8.95
	100.00	100.00	100.00	100.00	100.00	100.00	100.00

The analyses of limestones and shales above given were of samples taken from the property of Lou Hall.

Huffaker limestone quarry (Map location 15 F).—The Huffaker quarry is located on the North Rome and Attalla Railroad at Huffaker Station. Limestone of the Floyd formation is exposed over a thickness of 19 stratigraphic feet. The limestone is crinoidal, of a dark-blue color near the bottom of the exposure, becoming a light-blue to grayish-blue at the top. The quarry is an open pit. The overburden consists of about five feet of residual red clay. The total thickness of the limestone at this point is not known; however, it is probably not more than 50 feet. The dip is 10° W.

The following analysis shows the average chemical composition of the limestone over the entire exposure:

Analysis of Limestone from Huffaker Quarry

(Sample No. 99)

Lime (CaO)	54.38
Magnesia (MgO)	.25
Ferric oxide (Fe_2O_3)	.24
Sulphur trioxide (SO_3)	.00
Phosphorus pentoxide (P_2O_5)	tr.
Silica (SiO_2)	1.75
Clay bases	.30
Undetermined	43.08
	100.00

Little Dry Creek (Map location 16 F).—Limestone of the Floyd formation is exposed over a thickness of about 20 feet at a point 3½ miles north of Rome. The exposure is immediately beneath the bridge on the Rome-Summerville road which crosses Little Dry Creek. The limestone is heavy bedded, dark-blue to light-blue in color, and fairly uniform over the entire exposure. Chert is rather abundant seven feet above the base of the exposure.

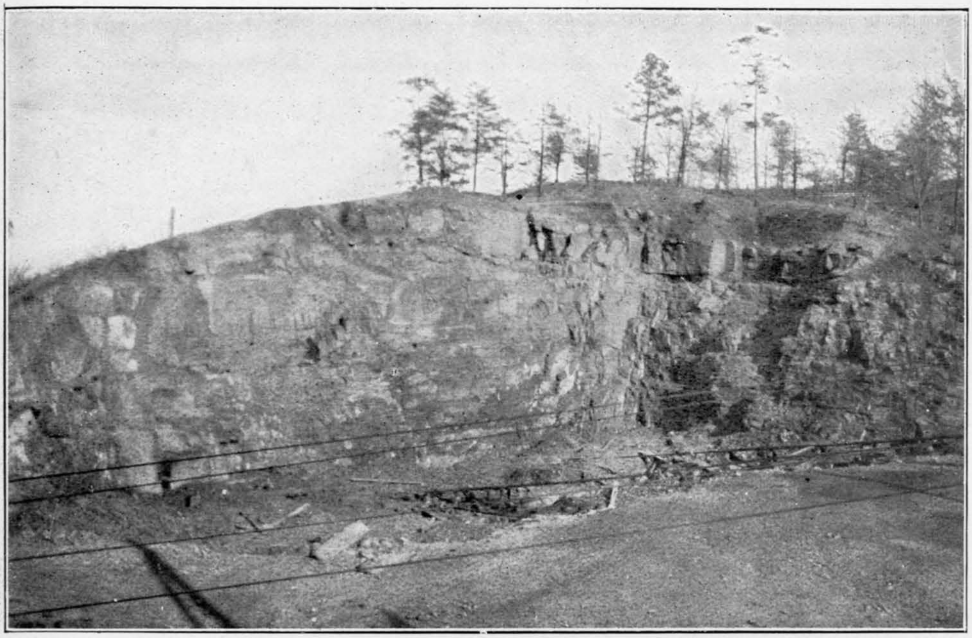
The following analysis shows the average chemical composition of the limestone at this point:

Analysis of Limestone from Little Dry Creek

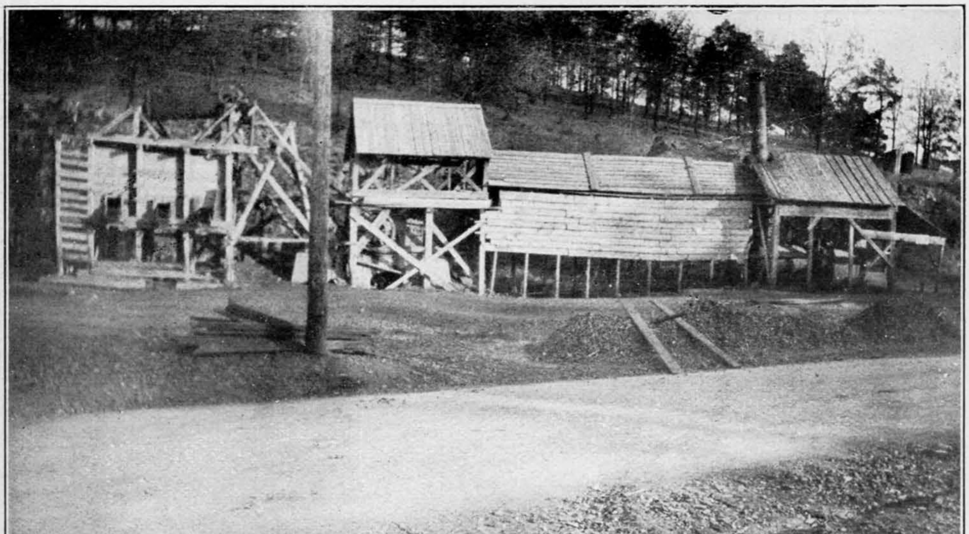
(Sample No. 100)

Lime (CaO)	50.84
Magnesia (MgO)	1.53
Ferric oxide (Fe_2O_3)	.96
Sulphur trioxide (SO_3)	.00
Phosphorus pentoxide (P_2O_5)	tr.
Silica (SiO_2)	3.50
Clay bases	.70
Undetermined	42.47
	100.00

Floyd County quarry (Map location 17 F).—The limestones of the Floyd formation are exposed in a quarry which has a vertical height



A. ARGILLACEOUS LIMESTONE IN THE FLOYD FORMATION. QUARRY LOCATED IN THE CITY LIMITS OF ROME AT THE INTERSECTION OF THE NORTH ROME AND ATTALLA RAILROAD AND THE ROME-SUMMERVILLE PUBLIC ROAD



B. STONE CRUSHING PLANT OWNED BY FLOYD COUNTY, LOCATED IMMEDIATELY EAST OF THE QUARRY IN A.

of from 20 to 30 feet in the city limits of Rome at the intersection of the North Rome and Attalla Railroad and the Rome-Summerville public road. The limestones have been worked extensively for road material. The Floyd formation at this point is very argillaceous and some portions of these rocks might be termed a calcareous shale.

The following analysis shows the average chemical composition of these rocks over the entire exposure:

Cemical Analysis of Limestone from Floyd County Quarry
(Sample No. 101)

Lime (CaO)	15.16
Magnesia (MgO)	1.72
Ferric oxide (Fe_2O_3)	4.04
Sulphur trioxide (SO_3)	.80
Phosphorus pentoxide (P_2O_5)	.00
Silica (SiO_2)	50.48
Clay bases	11.68
Loss on ignition	16.12
	100.00

D. B. F. Sellman property (Map location 18 F).—Two hundred feet east of the intersection of Heath Creek and the road leading from Crystal Springs to Little Texas Valley, an exposure of the Floyd limestone occupies the hill on the south side of the creek and extends over a stratigraphic thickness of 38 feet. The rocks strike N. 20° E. and dip 10° SE.

Section from Top to Bottom on Sellman Property

Sample No.	Unit No.	Description of Units	Thickness feet	Total Thickness feet
	3	Cherty, dark-blue limestone and chert	11	38
		Floyd formation		
102	2	Gray to grayish-blue, crinoidal limestone	27	27
	1	Shale		

The following analyses show the chemical composition of the limestone in the above section:

Analyses of Limestone from the Sellman Property

Sample No.	102	103[1]
Unit No.	2	
Lime (CaO)	49.32	50.56
Magnesia (MgO)	.82	1.20
Ferric oxide (Fe_2O_3)	1.36	.94
Sulphur trioxide (SO_3)	.00	.00
Phosphorus pentoxide (P_2O_5)	.00	.02
Silica (SiO_2)	5.20	4.20
Potash (K_2O)	--------	.18
Soda (Na_2O)	--------	.06
Clay bases	3.52	1.18
Loss on ignition	39.78	41.66
	100.00	100.00

Heath Creek exposure, Big Texas Valley (Map location 19 F).—The shales of the Floyd formation are exposed for about 15 stratigraphic feet at a point several hundred feet west of Heath Creek along the road leading from Orsman into Big Texas Valley. Some laminæ of limonite occur in the shale and were omitted in sampling.

The following analysis shows the chemical composition of the shales at this point:

Analysis of Shale from Heath Creek Exposure
(Sample No. 104)

Lime (CaO)	.62
Magnesia (MgO)	.08
Alumina (Al_2O_3)	14.18
Ferric oxide (Fe_2O_3)	4.25
Manganese (MnO)	.08
Titanium dioxide (TiO_2)	.63
Silica (SiO_2)	73.65
Loss on ignition	4.04
Moisture at 100° C.	1.20
	98.73

Orsman (Map location 20 F).—The limestone of the Bangor formation is exposed for a thickness of 12 stratigraphic feet in the lower portion of the formation at a point just east of the intersection of the

[1]Sample No. 103 was taken from a small exposure on the south side of the road near the bridge which crosses Heath Creek.

roads at Orsman leading into Big and Little Texas valleys respectively. The limestone is heavy-bedded and practically horizontal. The following section from the top of the exposure to the bottom shows its lithologic character:

Section at Orsman

Sample No.	Unit No.	Description of Units	Thickness feet	Total Thickness feet
	4	Dark-blue limestone with numerous layers of chert. (Not sampled on account of the abundance of chert it contained)	3.0	12.8
105	3	Dark-blue limestone with four thin layers of chert. (The chert was omitted in sample for analysis)	4.2	9.8
	2	Dark-blue crinoidal limestone	4.6	5.6
	1	Dark-blue fine-grained limestone	1.0	1.0

The following analysis shows the chemical composition of the limestone taken from the units 1, 2, and 3 of the section:

Analysis of Limestone from Orsman
(Sample No. 105)

Lime (CaO)	48.00
Magnesia (MgO)	.40
Ferric oxide (Fe_2O_3)	1.20
Sulphur trioxide (SO_3)	.08
Phosphorus pentoxide (P_2O_5)	.03
Silica (SiO_2)	6.28
Potash (K_2O)	.14
Soda (Na_2O)	.12
Clay bases	4.94
Loss on ignition	38.81
	100.00

One and one-half miles southwest of Orsman (Map location 21 F). —The heavy-bedded, fine-grained, dark-blue, crinoidal limestones of the Bangor formation are exposed at a point about 1½ miles southwest of Orsman. The limestone is to be seen over a thickness of about

10 feet in the lower portion of the formation. A layer of chert about 3 inches thick occurs at the top of the exposure.

The following analysis shows the composition of the entire exposure:

Analysis of Limestones 1½ Miles Southwest of Orsman
(Sample No. 106)

Lime (CaO)	53.80
Magnesia (MgO)	.25
Ferric oxide (Fe_2O_3)	1.16
Sulphur trioxide (SO_3)	.07
Phosphorus pentoxide (P_2O_5)	.00
Silica (SiO_2)	2.70
Loss on ignition	42.02
	100.00

Two miles southwest of Orsman (Map location 22 F).—The heavy-bedded, fine-grained, semi-crystalline, blue limestone of the Bangor formation occupies an exposure from the valley floor to a vertical height of 35 feet along the southeast side of Rocky Mountain on the property of J. B. Reaves. The limestone forms an extensive outcrop along the strike which is parallel to the mountain. The exposure is found in the lower portion of the formation and the beds dip from 5° to 10° NW.

The following analysis shows the average chemical composition of the limestone from the entire exposure:

Analysis of Limestone 2 Miles Southwest of Orsman
(Sample No. 107)

Lime (CaO)	53.13
Magnesia (MgO)	.60
Ferric oxide (Fe_2O_3)	1.42
Sulphur trioxide (SO_3)	.02
Phosphorus pentoxide (P_2O_5)	.00
Silica (SiO_2)	1.83
Loss on ignition	43.00
	100.00

Willingham-Harvey-Lipscomb property (Map location 23 F).—The limestone of the Bangor formation is exposed for about 40 stratigraphic feet at a point about three-fourths mile west of Orsman on the northeast end of Rocky Mountain on the property of Willingham, Harvey and Lipscomb. Above this 40 feet of limestone, residual material and sandstone float from the overlying Lookout formation conceal the underlying rocks, which are probably shales.

The exposure of limestone occupies a large area along the northeast end of the mountain. It is a dark-blue, somewhat fine-grained and partly crystalline, heavy-bedded, crinoidal limestone. The stone is very uniform in physical character over the entire exposure, with the exception of three or four cherty layers which are not more than one or two feet in thickness. The beds lie practically horizontal.

The following analysis shows the average chemical composition of the dark-blue limestone from the bottom of the exposure to the top, with the exception of the chert which was rejected in sampling:

Analysis of Limestone from the Willingham-Harvey-Lipscomb Property

(Sample No. 108)

Lime (CaO)	51.84
Magnesia (MgO)	.95
Ferric oxide (Fe_2O_3)	.78
Sulphur trioxide (SO_3)	.10
Phosphorus pentoxide (P_2O_3)	.00
Silica (SiO_2)	2.18
Potash (K_2O)	.10
Soda (Na_2O)	.11
Clay bases	1.79
Loss on ignition	42.15
	100.00

CHATTOOGA COUNTY

GEOLOGY

Connasauga Shales and Limestones

The Connasauga formation is made up essentially of fine-grained, argillaceous shales with interbedded limestones. The most western belt of this formation in Chattooga County occupies a narrow area in the valley paralleling the east front of Lookout Mountain. It contains considerable limestone. The silica-alumina ratio of the Connasauga shales is low, so that unless silica is added it cannot be used in the manufacture of Portland cement. The limestones in this formation in Chattooga County are always valley forming and as a considerable quantity of limestone occurs above water level nearby in the Bangor formation, it is hardly probable that the limestones of the Connasauga will ever become of any great economic importance.

Knox Dolomite

The Knox dolomite is only exposed in the upper portion of the formation. It consists of finely crystalline, gray dolomite with chert nodules and bedded chert. On account of the dolomitic character of this formation it is not suitable for use in the manufacture of Portland cement. The chert in the upper portion of the formation has been quarried extensively at Summerville for use as a road material and has been shipped throughout the South. When the dolomite occurs without chert it may be used commercially for the manufacture of lime and crushed-stone products.

Chickamauga Formation

The Chickamauga formation is characterized by two types of materials. In the eastern and central portions of the county it is made up largely of vari-colored, argillaceous shales with interbedded, mottled, earthy limestones, while in the western portion of the county the limestones are of greater thickness with few shales. The shales of this formation are usually too variable in chemical character and the silica-alumina ratio is too low for their use in the manufacture of Portland cement. The percentage of magnesia in the limestone is usually low and some beds of high-calcium stone occur interbedded with the argillaceous limestone. On account of the variable character of the limestones considerable care must be taken in the location of a quarry site, so that the stone will be of a uniform character over a sufficient thickness for economic development. The limestones usually carry too high a percentage of argillaceous material in this county to make a good commercial lime.

Rockwood Formation

The Rockwood formation is made up of sandstones and shales with some conglomerates in the eastern portion of the county, while to the west of Taylor Ridge the formation consists of shales with thin beds of interstratified sandstones. The shales of this formation, whenever found over a sufficient stratigraphic thickness to be quarried commercially, fill all the requirements for use in the manufacture of Portland cement. To the east of Taylor Ridge the formation contains so much interbedded sandstone that the shales cannot be commercially won. In the valley paralleling the east side of Lookout Mountain in what is known as Shinbone Ridge the sandstones are often absent for more than 200 stratigraphic feet, and as the shales dip at a considerable angle they can be easily quarried.

Floyd Formation

The Floyd formation consists chiefly of dark-colored, carbonaceous shales with some prominent dark-blue, heavy-bedded limestones which in many places are largely made up of the remains of crinoids. The limestones attain a thickness at some points of 100 feet. The silica-alumina ratio of the shales is usually slightly low for use in the manufacture of Portland cement. The high-calcium limestones are suitable at certain localities, chemically, for use in the manufacture of Portland cement; however, the conditions affecting development, such as the total thickness of the limestone at any one point, the amount of overburden to be removed, the chert contained in the formation, etc., must always be taken into consideration in the location of cement mills. The limestones of this formation are second only in importance to those of the Bangor formation. They are high grade, high-calcium stones, usually containing less than one-half of one per cent. of magnesia, while they contain some chert it is usually not in sufficient abundance to be of any very great objection.

Bangor Formation

The Bangor formation consists of both limestones and shales. The shales are dark brown or black, carbonaceous, and contain numerous interbedded sandstones in the upper portion of the formation. The shales are very uniform in the lower portion of the formation over a considerable thickness, and at many localities they satisfy all the conditions necessary for the manufacture of Portland cement. The limestone of the Bangor formation is always heavy bedded to massive, light grayish-blue or dark blue. In physical character the beds are amorphous to crystalline and often crinoidal or oölitic. The Bangor limestone contains very few magnesian beds east of Lookout Mountain, while along the base of certain portions of the mountain and to the west the magnesian beds are frequently interstratified with the high-calcium beds. The Bangor limestone makes an excellent commercial lime, both for building and agricultural purposes, road material, and ballast, while the high-calcium beds are well suited for fluxing purposes.

DESCRIPTION OF INDIVIDUAL LOCALITIES

Buckles limestone quarry (Map location 1 C).—The Buckels limestone quarry is located 1½ miles southeast of Chelsea on the east side of the State Road and on the property of R. M. Fenster. Lime was manufactured for local use during 1909 by William Buckles, who erected at this point a small bottle-shaped kiln.

The raw material consists of the Connasauga limestone, which is of dark-blue color and fairly uniform in lithologic character over the whole exposure. The limestone is valley forming and differs from the Connasauga limestone to the east in being almost free of secondary calcite and clayey intercalations. The quarry is about 10 feet deep and extends 40 feet across the strike and about 15 feet in a direction parallel to the strike. The strike is N. 12° E., and the dip 42° SE.

The following analysis shows the average chemical composition of the exposure at this point:

Analysis of Limestone from Buckels Quarry

(Sample No. 109)

Lime (CaO)	50.44
Magnesia (MgO)	3.44
Ferric oxide (Fe_2O_3)	.52
Silica (SiO_2)	.85
Clay bases	.41
Loss on ignition	44.34
	100.00

Two and one-half miles southeast of Trion (Map location 2 C).—The grayish-blue, fine-grained limestone of the upper portion of the Cannasauga formation is occasionally exposed at a point 2½ miles southeast of Trion on the property of William H. Penn. The exposure extends from the valley floor to a vertical height of more than 100 feet. The strike is N. 30° E., and the dip 40° SE.

The following analysis is an average of the entire exposure of the Connasauga limestone at this point:

Analysis of Limestone from the Penn Property
(Sample No. 110)

Lime (CaO)	50.48
Magnesia (MgO)	.25
Ferric oxide (Fe_2O_3)	.92
Sulphur trioxide (SO_3)	tr.
Silica (SiO_2)	5.67
Loss on ignition	42.68
	100.00

One and one-half miles north of Trion (Map location 3 C).—The rocks of the Knox dolomite occupy an exposure of about 52 stratigraphic feet at a point 1½ miles north of Trion. These rocks are heavy bedded and massive, although they often appear somewhat thin bedded, due to intercalated layers of argillaceous impurities. These calcareous rocks are fine grained and semi-crystalline. The beds vary in color, and a rather large quantity of chert is found in the upper portion of the exposure. The strike is N. 34° E., and the dip 25° SE.

Section 1 1/2 Miles North of Trion

Sample No.	Unit No.	Description of Units	Thickness feet	Total Thickness feet
	13	Weathered limestone with considerable chert	10	52.6
	12	Pink limestone 1 to 1½ feet thick, with considerable pink-colored chert in layers	7	42.6
	11	Fine-grained, heavy and thin-bedded limestone with slight pinkish cast	5.5	35.6
	10	Pinkish and green, fine grained, heavy-bedded limestone	5.5	30.1
	9	Heavy-bedded olive and gray limestone with pinkish cast containing some thin layers of impurities	8.4	24.6
	8	Thin-bedded, gray limestone with pinkish and greenish argillaceous impurities between these heavy beds	1.2	16.2
	7	Light-gray limestone	1	15
	6	Thin-bedded, pink and gray limestone with intercalated argillaceous impurities	1	14
	5	Dull-gray limestone with pinkish layers	2.5	13
	4	Heavy and thin-bedded pinkish limestone	8	10.5
	3	Greenish impure limestone (fault zone) the matrix consisting of argillaceous and siliceous limestone containing angular quartz	1	2.5
	2	Greenish impure limestone with much quartz	0.3	1.5
	1	Grayish-white extrememlyfine-grained limestone	1.2	1.2

Bald Mountain (Map location 4 C).—Bald Mountain is located 2½ miles due west of Summerville. The mountain extends in a northeast-southwest direction for about 1¾ miles. It is made up of the Chickamauga formation which at this point consists of red and green calcareous shales interstratified with some thin-bedded dark-blue high-calcium limestone. Dark-blue limestones predominate in the upper 100 feet of the mountain.

About one-fourth mile northeast of the southwestern end of the mountain in the upper 100 feet of the exposure the dark blue limestone was sampled. The following analysis shows the chemical character of the thin bedded dark blue limestone:

Analysis of Limestone from Bald Mountain
(Sample No. 111)

Lime (CaO)	50.18
Magnesia (MgO)	.35
Ferric oxide (Fe_2O_3)	1.10
Sulphur trioxide (SO_3)	tr.
Phosphorus pentoxide (P_2O_5)	.00
Insoluble (SiO_2, Al_2O_3, K_2O, Na_2O)	7.17
Loss on ignition	41.20
	100.00

Menlo (Map location 5 C).—Immediately west of the town of Menlo, on the road leading from Menlo to and across Sand Mountain, the Rockwood formation is largely exposed. A heavy-bedded, brown, somewhat unconsolidated sandstone occurs at the base of the formaton, above which occur yellowish-green and olive-green, arenaceous shales with many thin beds of flaggy sandstone.

Section from Top to Bottom, Exposure Near Menlo

Sample No.	Unit No.	Description of Units	Thickness feet	Total Thickness feet
	23	Devonian black shale	15	
	22	Concealed	56.6	870.8
	21	Brown sandstone with some calcareous sandstone and interstratified, pale-green arenaceous shale	33.5	814.2
	20	Yellowish-green and olive-green shale, interbedded with sandstone often calcareous	61.8	780.7
112	19	Yellowish-green and olive-green shales with an occasional thin bed of sandstone	76	718.9
113	18	Yellowish-green shale with a few thin beds of sandstone	98.5	642.9
	17	Reddish-brown somewhat hackly shale	12.2	544.4

Section from Top to Bottom, Exposure Near Menlo—Continued

Sample No.	Unit No.	Description of Units	Thickness feet	Total Thickness feet
	16	Yellowish-green shale	18	532.2
	15	Large *Pentamerous* sp. occur in argillaceous sandstone	18	512.4
	14	Olive-green arenaceous shale containing an occasional thin bed of grayish-brown sandstone	12.2	496.2
114	13	Olive-green arenaceous shale containing an occasional thin bed of grayish brown sandstone, also two thin seams of red hematite	61.7	484
	12	Concealed; few fragments of flaggy-sandstone on the surface	26.4	422.3
	11	Light-green to olive-green shale weathering somewhat hackly	33	395.9
	10	Concealed; principal ore bed of the formation in this unit	42.4	362.9
	9	Largely concealed; sandstone fragments are abundant on the surface; contains an abundant fauna—*Camarotoechia* sp., Trilobites, Corals, etc.	9.7	320.5
	8	Yellowish-green shales and thin-bedded brown sandstone	9.7	310.8
	7	Yellowish-green shale and thin-bedded green and brown sandstone; at the top of this unit, in thin brown sandstone, corals, *Camarotoechia*, and other brachiapods occur	9.7	301.1
	6	Thin-bedded, brown, flaggy sandstone largely concealed; at the top in flaggy sandstone were found *Camarotoechia* sp., corals, etc.	6.9	291.4
	5	Olive-green and yellowish-green shale with interbedded thin beds of brown flaggy sandstone; *Camarotoechia* sp. was found 22 feet below top	160.7	281.5
	4	Yellowish-green shale with some arenaceous shale	56.9	120.8
115	3	Yellowish-green and olive-green shales	27.1	63.9
	2	Thin and heavy-bedded sandstone	29.5	36.8
	1	Thin-bedded ferruginous sandstone	7.3	7.3
		Chickamauga formation, thin-bedded dark-blue limestone	0.0	0.0

Analyses of Shales from Near Menlo

Sample No.	112	113	114	115
Unit No.	19	18	13	3
Moisture at 100 C	.51	.45	.70	.72
Loss on ignition	8.05	5.50	6.30	7.95
Soda (Na_2O)	--------	--------	.28	1.42
Potash (K_2O)	--------	--------	.42	3.29
Lime (CaO)	tr.	tr.	--------	tr.
Magnesia (MgO)	1.02	.53	1.30	1.26
Alumina (Al_2O_3)	13.93	15.40	21.86	21.26
Ferric axide (Fe_2O_3)	5.71	5.71	7.48	9.07
Titanium dioxide (TiO_2)	.82	.82	.92	1.08
Silica (SiO_2)	71.49	69.35	60.78	54.85
	101.53	97.76	100.04	100.90

Shackleton (Map location 6 C).—The heavy-bedded, dark-blue limestones of the Floyd formation are exposed on the north side of a small creek just southeast of the town of Shackleton. The limestones are exposed over a stratigraphic thickness of 92 feet above which occur the carbonaceous dark-brown shales of the same formation.

Section from Top to Bottom, Exposure Near Shackleton

Sample No.	Unit No.	Description of Units	Thickness feet	Total Thickness feet
116	3	Heavy and thin-bedded dark-blue siliceous crinoidal limestone	53.4	92.3
	2	Dark-blue limestone, containing chert scattered throughout, at the top occurs a layer of chert 8 inches thick	14	38.9
	1	Heavy-bedded, dark-blue crinoidal limestone; somewhat massive near the top	24.9	24.9

The following analysis shows the average composition of the limestone over the entire exposure:

Analysis of Limestone Near Shackleton
(Sample No. 116)

Lime (CaO)	49.50
Magnesia (MgO)	.25
Alumina (Al_2O_3) / Ferric oxide (Fe_2O_3)	1.18
Sulphur trioxide (SO_3)	.04
Silica (SiO_2)	10.39
Loss on ignition	38.64
	100.00

Immediately opposite the exposure described above and on the south side of the creek the Floyd limestone is exposed over a thickness of about 100 feet. The following analysis shows the average composition of this limestone over the entire exposure:

Analysis of Limestone from South Side of Creek Near Shackelton
(Sample No. 117)

Lime (CaO)	52.68
Magnesia (MgO)	.20
Alumina (Al_2O_3) / Ferric oxide (Fe_2O_3)	1.40
Sulphur trioxide (SO_3)	tr.
Silica (SiO_2)	4.18
Loss on ignition	41.54
	100.00

Gore (Map location 7 C).—About one-fourth mile east of Gore on the south side of the Gore-Kartah public road the dark-blue limestone of the Floyd formation is exposed in places from the base of the ridge to the top. The surface of the ridge is covered with a mantle of brown sandstone and loose chert. The exposure of limestone was not sampled at this point.

Two miles northeast of Gore (Map location 8 C).—The limestones and shales of the Floyd formation are well exposed south of the second-class road connecting the Gore-Subligna public road with the Kartah-Subligna road.

The section from the top of Gaithers Ridge to the bottom is as follows:

Section 2 Miles Northeast of Gore

Sample No.	Unit No.	Description of Units	Thickness feet	Total Thickness feet
118	2	Dark-brown, carbonaceous shales, largely concealed	100	150
119	1	Dark-bluish-gray limestone consisting largely of crinoid stems; Brachiapods and Bryozoa are also occasionally found	50	50
		Base of ridge	0	0

The Floyd shales outcrop along the south side of the road on the east side of the ridge.

Analysis of Limestone and Shale 2 Miles Northeast of Gore

Sample No.	118	119	120[1]
Unit No.	2	1	
Moisture at 100 C	.92	--------	1.76
Loss on ignition	2.38	43.82	7.52
Soda (Na_2O)	--------	--------	.71
Potash (K_2O)	--------	--------	.98
Lime (CaO)	.77	53.16	2.83
Magnesia (MgO)	.29	.40	1.29
Alumina (Al_2O_3)	6.84	--------	21.63
Ferric oxide (Fe_2O_3)	5.75	.56	4.81
Silica (SiO_2)	83.00	2.06	57.83
Sulphur trioxide (SO_3)	--------	.00	--------
Phosphorus pentoxide (P_2O_5)	--------	.00	--------
Maganese (MnO)	.07	--------	.08
Titanium dioxide (TiO_2)	.27	--------	.81
	100.39	100.00	100.25

Four miles southwest of Subligna (Map location 9 C).—Four miles southwest of Subligna the limestones of the Floyd formation are exposed on both the northeast and southwest sides of a creek which intersects the ridge at this point. The limestone is both underlain and

[1]Floyd shales along the south side of the road on the east side of the ridge.

overlain by shale of the same formation. The hill reaches a height of about 100 feet above the valley.

The following analysis shows the average chemical composition of the entire exposure of the limestone:

Analysis of Limestone 4 Miles Southwest of Subligna

(Sample No. 118a)

Lime (CaO)	48.64
Magnesia (MgO)	.20
Ferric oxide (Fe_2O_3)	2.40
Sulphur trioxide (SO_3)	.06
Phosphorus pentoxide (P_2O_5)	....
Silica (SiO_2)	7.76
Loss on ignition	40.94
	100.00

Subligna (Map location 10 C).—The limestone of the Floyd formation is exposed in the extreme northeastern portion of Gaithers Ridge, about 2,000 feet northeast of Subligna. Shales and thin-bedded sandstones overlie the limestones and attain a thickness of from 20 to 30 feet.

The following analysis represents the composition of the whole exposure at this point

Analysis of Limestone from Subligna

(Sample No. 119a)

Lime (CaO)	49.64
Magnesia (MgO)	.60
Ferric oxide (Fe_2O_3)	.88
Sulphur trioxide (SO_3)	.10
Phosphorus pentoxide (P_2O_3)	tr.
Silica (SiO_2)	5.14
Potash (K_2O)	.28
Soda (Na_2O)	.18
Clay bases	1.88
Loss on ignition	41.30
	100.00

One and one-half miles northwest of Crystal Springs (Map location 11 C).—The limestones and shales of the Bangor formation are occasionally exposed along the hillsides 1½ miles northwest of Crystal

Springs at a point about 1,000 feet southeast of the coered bridge which crosses West Armuchee Creek on the Rome-Summerville road. The shales overlie the limestones. They are of a dark bluish-black color and characteristically fissile, while the limestone is heavy bedded and dark-blue in color.

The following analyses show the chemical character of the limestones and shales at this point:

Analyses of Limestone and Shale 1 1/2 Miles Northwest of Crystal Springs.

Sample No.	Limestone 120a	Shale 121
Moisture at 100° C		3.47
Loss on ignition	41.75	7.18
Soda (Na_2O)	.17	.61
Potash (K_2O)	.35	2.20
Lime (CaO)	50.94	.94
Magnesia (MgO)	1.02	1.00
Alumina (Al_2O_3)		19.93
Ferric oxide (Fe_2O_3)	.80	5.10
Silica (SiO_2)	3.21	59.31
Sulphur trioxide (SO_3)	.15	
Phosphorus pentoxide (P_2O_5)	.04	
Manganese (MnO)		.06
Titanium dioxide (TiO_2)		.54
Clay bases	1.57	
	100.00	100.34

Tidings (Map location 12 C).—The dark-blue, black, and olive-green shales of the Bangor formation are exposed in a low hill over a stratigraphic thickness of 15 feet on the west side of West Armuchee Creek at Tidings.

Three-fourths of a mile northwest of Tidings about five feet of heavy-bedded dark-blue limestone of the Bangor formation is exposed. The beds of limestone and shale lie practically level.

The following analyses show the chemical composition of the limestone and shale:

Analyses of Limestone and Shale Near Tidings.

Sample No.	Limestone 122	Shale 123
Moisture at 100° C.	----------	1.38
Loss on ignition	41.30	4.50
Soda (Na_2O)	.20	.49
Potash (K_2O)	.24	1.80
Lime (CaO)	52.00	.78
Magnesia (MgO)	.30	.86
Alumina (Al_2O_3)	----------	14.33
Ferric oxide (Fe_2O_3)	.74	4.59
Silica (SiO_2)	3.41	70.79
Sulphur trioxide (SO_3)	.08	--------
Phosphorus pentoxide (P_2O_5)	.00	--------
Manganese (MnoO)	----------	.10
Titanium dioxide (TiO_2)	----------	.81
Clay bases	1.73	--------
	100.00	100.43

One and one-half miles north of Kartah (Map location 13 C).—The Bangor shales (Pennington) are well exposed 1½ miles north of Kartah on the west side of Little Sand Mountain and along the second-class road which extends from the valley to the top of the mountain.

At the base of the section in the valley of West Armuchee Creek occur occasional outcrops of shales and thin-bedded flaggy sandstones bearing ripple marks, which belong to the Floyd formation. The Bangor limestones lie immediately above the Floyd shale, but are comparatively thin at this point and are largely concealed. They outcrop, however, on the west side of Little Sand Mountain in this vicinity where they are exposed over a thickness of about 40 feet. Immediately above the limestones of the Bangor formation occur the Bangor shales. The lower 230 feet of the shales vary in color from a grayish-blue to green and black and become more siliceous towards the top. The upper 30 feet of the exposure consists of thin-bedded sandstones and shales interstratified.

The following analysis shows the chemical character of the lower 230 feet of the shale exposure:

Analysis of Shale, Valley West of Armuchee Creek
(Sample No. 124)

Moisture at 100° C.	1.62
Loss on ignition	6.14
Soda (Na_2O)	1.42
Potash (K_2O)	.38
Lime (CaO)	.73
Magnesia (MgO)	1.11
Alumina (Al_2O_3)	19.24
Ferric oxide (Fe_2O_3)	6.97
Manganese (MnO)	.11
Titanium dioxide (TiO_2)	.92
Silica (SiO_2)	61.28
	99.92

Gaines property (Map location 14 C).—The heavy-bedded, dark-blue limestone of the Bangor formation is exposed on the L. P. Gaines property two miles northeast of Kartah, on the west side of Little Sand Mounain. The limestones extend from the base of the mountain over a vertical and stratigraphic height of 81 feet.

Section on Property of L. P. Gaines

Sample No.	Unit No.	Description of Units	Thickness feet	Total Thickness feet
125	3	Dark blue limestone with some chert nodules	40	81
126[1] 127[2]	2	Siliceous cherty, nodular limestone	8	41
128	1	Heavy-bedded dark-blue to bluish-gray crinoidal limestone with many brachiapods	33	33
		Base of section	0	0

The following analyses show the chemical composition of the individual beds described in the above section:

[1]Limestone.
[2]Chert.

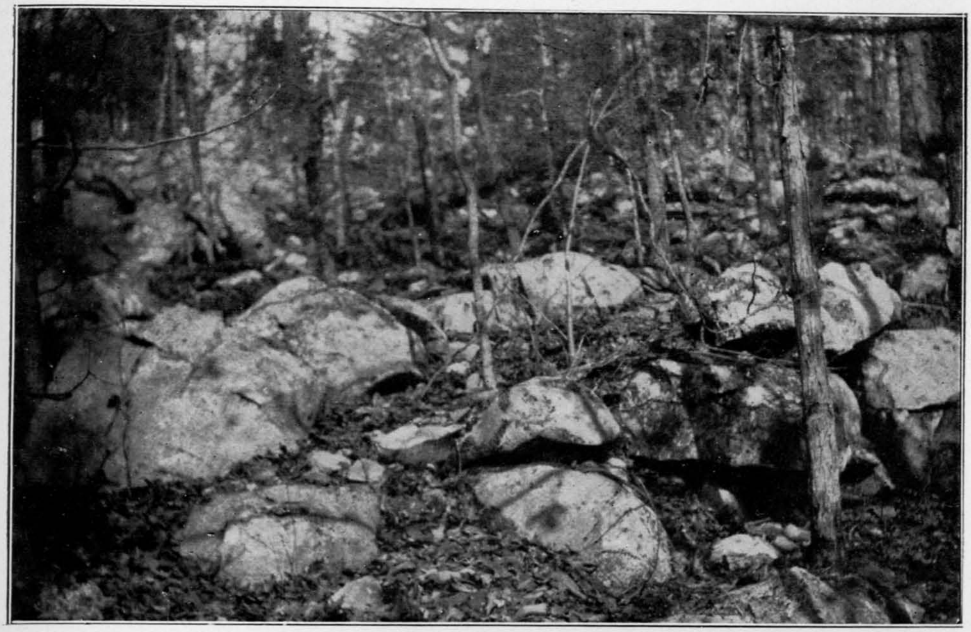
Analyses of Limestone and Chert from the Gaines Property

Sample No.	125	126	127	128
Unit No.	3	2	2	1
Lime (CaO)	52.10	43.86	30.26	51.50
Magnesia (MgO)	2.14	4.04	.60	1.16
Ferric oxide (Fe_2O_3)	.66	1.54	1.80	.80
Sulphur trioxide (SO_3)	.02	.15		.00
Phosphorus pentoxide (P_2O_5)		.04		
Silica (SiO_2)	2.45	9.96	41.28	4.60
Potash $K(_2O)$		.17		
Soda (Na_2O)		.14		
Clay bases		1.50		
Loss on ignition	42.63	38.60	26.06	41.94
	100.00	100.00	100.00	100.00

Robinson property (Map location 15 C).—The brown carboniferous shales of the Floyd formation are exposed at a point about five miles north of Crystal Springs. The limestone is exposed for about

Section on Robinson Property

Sample No.	Unit No.	Description of Units	Thickness feet	Total Thickness feet
		Concealed; soil and float of the lookout sandstone		
	8	Bluish-gray argillaceous limestone	5.6	277.5
129	7	Dark-bluish-gray, heavy-bedded limestone	9.6	271.9
130	6	Bluish-gray, heavy-bedded limestone	25	262.3
	5	Cherty limestone	1.7	237.3
131	4	Light-blue, heavy-bedded limestone	90	235.6
132	3	Dark-blue, heavy-bedded limestone, containing Crinoids and Bryozoa in abundance	80	145.6
133	2	Dark-blue, heavy-bedded to massive crinoidal limestone. (A few chert nodules were observed at the top and the bottom of this unit	45.6	65.6
	1	Dark-brown carbonaceous shales	20	20
		Base of the mountain	0	0



A. BANGOR LIMESTONE, ABOUT 5 MILES NORTH OF CRYSTAL SPRINGS, ON THE ROBINSON PROPERTY, CHATTOOGA COUNTY, GEORGIA

B. SHALES AT THE TOP OF THE FLOYD FORMATION, ABOUT 5 MILES NORTH OF CRYSTAL SPRINGS ON THE ROBINSON PROPERTY, CHATTOOGA COUNTY, GEORGIA

20 stratigraphic feet along the second-class road which follows around this spur of Little Sand Mountain.

The heavy-bedded, dark-blue limestones of the Bangor formation lie immediately above the shales. The lower 45 feet of the limestone is exposed to the west of the residence of Mr. Robinson, while above this the remaining portion of the exposure lies just east of the house and on the west side of the mountain.

The above section shows the lithologic character of the limestones and shales from top to bottom over the entire exposure:

The following analyses show the chemical composition of the limestones described in the above section:

Analyses of Limestone from the Robinson Property

Sample No.	129	130	131	132	133
Unit No.	7	6	4	3	2
Lime (CaO)	51.58	51.84	52.94	50.10	53.02
Magnesia (MgO)	.40	.95	.36	.30	1.44
Ferric oxide (Fe_2O_3)	1.04	.78	1.02	.98	.58
Sulphur trioxide (SO_3)	.06	.10	tr.	tr.	.00
Silica (SiO_2)	3.00	2.18	2.85	5.42	1.77
Clay bases	2.79	1.79	--------	--------	--------
Loss on ignition	41.13	42.36	42.83	43.20	43.19
	100.00	100.00	100.00	100.00	100.00

Two miles west of Menlo (Map location 16 C).—The sandstones and shales of the Lookout formation are largely exposed about two miles west of Menlo on the road leading from Menlo to and across Sand Mountain, lying unconformably upon the shales (Pennington) of the Bangor. The rocks strike N. 45° E., and dip 15° NW.

The following section begins at the top of the Lookout formation and extends well down in the shales of the Bangor:

Section 2 Miles West of Menlo

Sample No.	Unit No.	Description of Units	Thickness feet	Total Thickness feet
	8	Top of the mountain to sandstone quarry	38.6	337.6
	7	Brownish-gray and white sandstone and conglomerate	28.9	299
	6	Dark-blue and brown carbonaceous shales with thin beds of fire clay thin beds of sandstone predominate near the bottom of this unit	28.9	270.1
	5	Thin and heavy-bedded brown sandstone	19.3	241.2
		Yellowish-green argillaceous shale	53.1	221.9
	4	Heavy-bedded grayish-brown sandstone	62.7	168.8
	3 2	Argillaceous shales with interbedded sandstones; 10 feet of sandstones at the bottom of this unit	106.1	106.1
	1	Bangor formation (Pennington shales) yellowish-green and yellow argillaceous shales; the unit is largely concealed		

Cedar Point (Map location 17 C).—The limestones of the Bangor formation are exposed on the property of J. M. Lawrence at Cedar Point, about 1½ miles west of Menlo, over a vertical height of about 200 feet and extend from the base of the cliff to the top. The limestones are heavy bedded and massive, grayish blue and dark blue in color, and partly crystalline. Unit 4 consists largely of fine-grained magnesian limestone.

The section from the top of the exposure of limestone to the base of the cliff is as follows:

Section at Cedar Point

Sample No.	Unit No.	Description of Units	Thickness feet	Total Thickness feet
134	5	Semi-crystalline, grayish-blue heavy bedded and massive limestone with one or two layers of fine-grained limestone	46.4	192.4
135	4	Partly concealed; dark-blue, heavy-bedded, fine grained limestone	21.4	146.0
136	3	Heavy-bedded, grayish-blue, semi-crystalline limestone	34.8	124.6
137	2	Gray to grayish-blue, heavy-bedded semi-crystalline limestone; the unit is partially concealed in the lower portion	63.6	89.8
	1	Comcealed	26.2	26.2
		Road at the base of the cliff	0	0

The following analysis will show the composition of the individual beds described above:

Analyses of Limestone at Cedar Point

Sample No.	134	135	136	137
Unit No.	5	4[1]	3	2
Lime (CaO)	52.36	54.06	54.12	53.95
Magnesia (MgO)	.08	.08	.12	.20
Ferric oxide (Fe_2O_3)	.74	.52	1.12	.62
Sulphur trioxide (SO_3)	-------	-------	-------	.02
Phosphorus pentoxide (P_2O_5)	-------	-------	-------	.03
Clay bases	.94	1.02	.79	.98
Loss on ignition	45.88	44.32	43.85	44.20
	100.00	100.00	100.00	100.00

Neal Gap (Map location 18 C).—Yellowish-green and dark-brown shales of the Lookout formation outcrop 1½ miles southeast of Gilreath mill along the Neal Gap road. The shales are interbedded with brown sandstones. The strike is N. 50° E. and the dip 17° SE.

[1]Magnesian limestone rejected in sampling this unit.

The following analysis shows the chemical character of the exposure of shales which lie immediately above the heavy-bedded brown sandstone at the base of the Lookout formation:

Analysis of Shale from Neal Gap
(Sample No. 138)

Moisture at 100° C.	.50
Loss on ignition	3.68
Soda (Na_2O)	.48
Potash (K_2O)	.62
Lime (CaO)	.64
Magnesia (MgO)	.73
Alumina (Al_2O_3)	12.08
Ferric oxide (Fe_2O_3)	4.70
Titanium dioxide (TiO_2)	.92
Silica (SiO_2)	75.50
	99.85

Martins Cave (Map location 19 C).—The limestone of the Bangor formation is exposed about 1½ miles northeast of Teloga. The limestone occupies an exposure of 155 feet, and is concealed by the overlying float. The stone is heavy bedded and massive, of dark-blue color and many of the beds are largely crinoidal. The strike is N. 30° E., and the dip 10° SE.

Section from Top to Bottom, Martins Cave

Sample No.	Unit No.	Description of Units	Thickness feet	Total Thickness feet
139	2	Dark-blue, heavy-bedded limestone with a good number of crinoid stems; the limestone is entirely crinoidal in places	54.1	152.6
140	1	Dark-blue, heavy-bedded limestone, largely crinoidal	98.5	98.5
		Mouth of cave	0	0

The following analyses show the chemical composition of the units described in the above section:

Analyses of Limestone from Martins Cave

Sample No.	139	140
Unit No.	2	1
Lime (CaO)	53.14	53.22
Magnesia (MgO)	1.56	.86
Ferric oxide (Fe_2O_3)	.50	.16
Silica (SiO_2)	.90	2.19
Clay bases	.47	.85
Loss on ignition	43.43	42.72
	100.00	100.00

DADE COUNTY

GEOLOGY

Chickamauga Formation

The Chickamauga formation in Dade County is made up essentially of argillaceous and high-calcium, thin-bedded limestones. The limestones vary both in their lithologic and chemical character. All of the beds carry a low percentage of magnesia and are chemically suitable for use in the manufacture of Portland cement. They may also be used to advantage for road metal, ballast, and concrete. Their high argillaceous content makes them objectionable for fluxing purposes.

Rockwood Formation

This formation consists essentially of shales with few sandstones and some interbedded limestones. It contains the red fossil iron ore which has been extensively mined in the vicinity of Rising Fawn. The shales are seldom uniform over any considerable thickness, and contain a low percentage of magnesia. The silica-alumina ratio is nearly always as much as 3 to 1 and as a rule the shales are chemically suitable for use in the manufacture of Portland cement. Careful location of quarry sites is necessary in order that the conditions which affect development may be satisfactory.

Bangor Formation

The Bangor formation, as mapped by Hayes[1] in this county, con-

[1]Hayes, C. W., Stevenson folio (No. 19), Geol. Atlas U. S., U. S. Geol. Survey, 1895.

sists of both limestones and shales. The shales are separated from the underlying limestones by an unconformity and are equivalent to the Pennington shales of Tennessee. The limestones vary in their lithologic character. Along the west side of Lookout Mountain the Bangor limestone contains a large amount of chert in the upper and lower portions of the formation. Many of the beds are high in silica and argillaceous impurities, while the percentage of magnesia is always very low. There are, however, large exposures of this limestone which are entirely free of chert and which are commercially available for use in the manufacture of lime products and cement.

The exposures of this limestone in Sand Mountain show it to contain many beds of chert and also many beds high in magnesia. The magnesian limestone can always be told by its very fine grained or amorphous character and its smooth conchoidal fracture, together with a somewhat dark-blue color. The magnesian stone is suitable only for the manufacture of lime and crushed stone products.

The shales which unconformably overlie the limestones of the Bangor formation and underlie the Lookout sandstones and shales have a silica-alumina ratio of at least 3 to 1. They are somewhat variable in their chemical composition, but are entirely suitable at certain localities for use as a mix in the manufacture of Portland cement.

Lookout Formation

The Lookout formation contains siliceous brown carbonaceous shales with some interbedded sandstone; a massive sandstone occurs at the base and conglomeratic sandstone at the top of the formation. The silica-alumina ratio in these shales is high, often approaching 5 to 1. The shales of the Lookout formation, as well as the Pennington shales, both overlie the Bangor limestone, so that at certain localities where the limestones are commercially available and chemically suitable for the manufacture of cement, it ought to be possible to secure the shales from the above formation. On account of the occurrence of many beds of sandstone with the Lookout shale and the usual overburden which accompanies this formation, quarries can be located only after a thorough knowledge has been gained of the physical and chemical character of the shales at any one point.

DESCRIPTION OF INDIVIDUAL LOCALITIES

Trenton (Map location 1 D).—The Chickamauga limestone is exposed along the road between Trenton and Sand Mountain. The limestone is thin bedded, fine grained, of light to dark blue color, and contains some argillaceous beds. The section below begins at the intersection of the White Oak and Higdon-Trenton roads.

Section Near Trenton

Sample No.	Unit No.	Description of Units	Thickness feet	Total Thickness feet
	7	Thin-bedded, argillaceous limestone largely concealed	45.8	512.5
	6	Concealed	19.9	466.7
	5	Dark-blue limestone exposed for 5 feet at the base; remaining portion of unit concealed	56.5	446.8
141	4	Thin-bedded, dark-blue argillaceous limestone	165.1	390.3
	3	Concealed	72.4	225.2
142	2	Argillaceous, thin-bedded limestone with some chert	101.7	152.8
143	1	Thin-bedded high-callcium limestone	51.1	51.1
		The limestone is largely concealed below this unit	0	0

The following analyses show the chemical composition of the several units described in the above section:

Analyses of Limestone Near Trenton

Sample No.	141	142	143
Unit No.	4	2	1
Lime (CaO)	53.78	42.72	52.68
Magnesia (MgO)	.62	.65	.66
Ferric oxide (Fe_2O_3)	1.16	1.30	.52
Silica (SiO_2)	.90	14.38	2.96
Clay bases	.57	4.32	1.20
Loss on ignition	42.97	36.63	41.98
	100.00	100.00	100.00

Tatum (Map location 2 D).—Tatum is located about 20 miles south of Chattanooga on the Alabama Great Southern Railroad. Shales are exposed at this point in the lower portion of the Rockwood formation for about 15 to 20 feet along the hillside.

The following analysis shows the average chemical composition of the shale:

Analysis of Shale from Tatum

(Sample No. 144)

Moisture at 100° C.	.50
Loss on ignition	6.94
Lime (CaO)	.38
Magnesia (MgO)	1.28
Alumina (Al_2O_3)	21.40
Ferric oxide (Fe_2O_3)	9.58
Titanium dioxide (TiO_2)	1.28
Silica (SiO_2)	55.69
	97.05

One-half mile west of Trenton (Map location 3 D).—The Rockwood formation is well exposed one-half mile west of Trenton along the White Oak Gap road, just east of the run at the base of the mountain. The formation contains some thin beds of limestone and some red iron ore near the top. Sandstones are almost entirely absent in this formation throughout the Lookout Valley. The following section begins at the base of the upper thin bed of limestone in the Rockwood formation:

Section One-Half Mile West of Trenton

Sample No.	Unit No.	Description of Units	Thickness feet	Total Thickness feet
	5	Argillaceous thin-bedded limestone some low grade ore at the base of this unit	4.8	128.2
	4	Argillaceous limestone	2.4	123.4
	3	Comcealed	80.7	120.0
	2	Largely concealed with sone arenaceous shale	9.6	40.3
145	1	Olive-green shale with some thin-bedded argillaceous limestomes and some sandy beds	30.7	30.7

The following analysis shows the composition of the shales at the base of the section:

Analysis of Shale One-Half Mile West of Trenton

(Sample No. 145; Unit No. 1)

Moisture at 100° C	.71
Loss on ignition	6.23
Lime (CaO)	.10
Magnesia (MgO)	2.00
Alumina (Al_2O_3)	16.72
Ferric oxide (Fe_2O_3)	7.06
Titanium dioxide (TiO_2)	.76
Silica (SiO_2)	64.13
	94.71

One mile northwest of New England (Map location 4 D).—Occasional exposures of an olive-green shale of the Rockwood formation occur along the roadside one mile northwest of New England. The shale is very uniform and has but little interbedded sandstone.

The following analysis shows the average chemical composition of the shale exposed at this point:

Analysis of Shale One Mile Northwest of New England

(Sample No. 146)

Moisture at 100° C	.46
Loss on ignition	5.04
Lime (CaO)	2.86
Magnesia (MgO)	1.32
Alumina (Al_2O_3)	16.62
Ferric oxide (Fe_2O_3)	6.72
Titanium dioxide (TiO_2)	.82
Silica (SiO_2)	63.42
	97.26

One and three-fourths miles south of Rising Fawn (Map location tion 5 D).—The shales of the Rockwood formation are exposed at a point 1¾ miles south of Rising Fawn along the Rising Fawn-Sulphur Springs public road. The shales are yellowish and olive-green in color and are free from interbedded sandstone.

The section below begins 390 feet west of the intersection of the Rising Fawn-Sulphur Springs road and the road to Cloverdale. The strike is N. 52° W. and the dip 29° NE.

Section 1 3/4 Miles South of Rising Fawn

Sample No.	Unit No.	Description of Units	Thickness feet	Total Thickness feet
147	3	Olive-green and yellowish-green argillaceous shale	61.5	180.3
	2	Concealed	46.7	118.8
	1	Olive-green, fissile, argillaceous shale	72.1	72.1

Analysis of Shale 1 3/4 Miles South of Rising Fawn

(Sample No. 147; Unit No. 1 and 3)

Moisture at 100° C	.64
Loss on ignition	6.42
Lime (CaO)	tr.
Magnesia (MgO)	1.25
Alumina (Al_2O_3)	19.37
Ferric oxide (Fe_2O_3)	8.40
Titanium dioxide (TiO_2)	.99
Silica (SiO_2)	59.42
	96.49

Southern Iron and Steel Company (Map location 6 D).—The limestone quarries of the Southern Iron and Steel Company are located one mile northeast of Rising Fawn at the southern end of a spur of Lookout Mountain. The lower quarry extends from the base of the mountain to a height of about 53 feet. This quarry was long ago abandoned on account of the great quantity of chert contained in the limestone. The limestone in the upper quarry is exposed over a vertical height of about 120 feet.

The section made at this point begins at the top and on the point of the mountain. The sandstone and conglomerate of the Lookout formation is well exposed at the top of the mountain, while the shales of the same formation are largely concealed by the float from the overlying sandstone. Below the Lookout formation the shales and limestones of the Bangor formation are exposed and extend to the bottom of the mountain. The limestones are grayish blue and dark blue, heavy bedded and massive, and contain some argillaceous and cherty beds. The strike and dip at the top of the upper quarry were found to be N. 55° E. and 10° NW., respectively.

The section from the top to the bottom of the mountain is as follows:

Section at the Quarries of the Southern Iron and Steel Company

Sample No.	Unit No.	Description of Units	Thickness feet	Total Thickness feet
	38	Sandstone and Conglomerate	49	955.2
	37	Shale concealed largely by thin covering of residual soil	316	906.2
	36	Argillaceous limestones with some beds of bluish-gray, high-calcium limestone	75	590.2
148	35	Blue limestone	35	515.2
149	34	Blue limestone, some chert at the bottom	90	480.2
150	33	Limestone, argillaceous at the bottom	100	390.2
	32	Concealed cherty limestone	10	290.2
151	31	Somewhat argillaceous and impure limestone	60	280.2
152	30	Heavy-bedded, grayish-blue limestone containing some crinoidal limestone and breaking with an uneven fracture; one foot of earthy blue limestone 6 feet below the top	11	220.2
153	29	Argillaceous, fine-grained, blue limestone	2.7	209.2
154	28	Bluish-gray, heavy-bedded, fine-grained limestone	3.5	206.5
	27	Dark-blue, fine-grained, heavy-bedded and massive limestone	9.6	203
155	26	Dark-blue, heavy-bedded limestone somewhat oölitic, being the topmost ledge quarried in the extreme northeast end of the quarry	8	193.4
156	25	Impure limestone containing brachiapods, *Spirifer*, sp. etc., and layers of hard argillaceous grayish-blue limestone	.7	185.4
157	24	Heavy-bedded and massive grayish-blue limestone containing corals and brachiapods	14.1	184.7
158	23	Grayish-blue, heavy-bedded limestone one foot of earthy limestone at the top	4	170.6
159	22	Semi-crystalline, heavy-bedded, gray, limestone; the lower portion somewhat oölitic and the whole unit containing layers and lenses of clayey impurities	3.8	166.6
160	21	Grayish-blue to dark-blue, heavy-		

Section at the Quarries of the Southern Iron and Steel Co.—Continued

Sample No.	Unit No.	Description of Units	Thickness feet	Total Thickness feet
		bedded and massive, often crinoidal, limestone; some layers of flint a foot above the bottom of the unit	10.8	162.8
161	20	Grayish-blue, massive semi-crystalline limestone with some chert near the bottom	5	152
162	19	Heavy-bedded argillaceous limestone with a greenish cast	6	147
163	18	Fine-grained dark grayish-blue, heavy-bedded and massive limestone	7	141
164	17	Grayish-blue, largely crystalline, heavy-bedded and massive limestone containing considerable amount of chert in the upper two feet	4	134
	16	Green shale containing a great abundance of chert scattered throughout the lower four feet; not sampled	8.4	130
165	15	Grayish-blue, heavy-bedded and massive limestone	7.6	121.6
166	14	Fine-grained, grayish blue, heavy-bedded and massive limestone	16.8	114.0
167	13	Fine-grained, grayish-blue, heavy-bedded and massive limestone	4.7	97.2
	12	Fine-grained, bluish-gray, heavy-bedded and massive limestone filled with chert; not sampled	5.5	92.5
168	11	Massive, somewhat fine-grained, dark grayish-blue limestone	9	87
169	10	Bluish-gray, somewhat fine-grained limestone	4.8	78
	9	Cherty limestone from quarry level of upper quarry to top of quarry below; not sampled	20	73.2
	8	Cherty limestone; not sampled	17	53.2
170	7	Dark grayish-blue, fine-grained limestone with some layers of crinoid stems	4	36.2
170	6	Heavy-bedded, fine-grained gray limestone with a conchoidal fracture and weathering much like a lithographic stone	3.7	32.2
170	5	Heavy-bedded, light grayish-blue, fine-grained limestone becoming thin-bedded near the top	6.8	28.5

Section at the Quarries of the Southern Iron and Steel Co.—Continued

Sample No.	Unit No.	Description of Units	Thickness feet	Total Thickness feet
	4	Fine-grained gray and grayish-blue, massive and heavy-bedded limestone the lower portion being thin-bedded and the whole unit containing chert; not sampled	7.1	21.7
171	3	Dark-blue to grayish-blue, fine-grained massive limestone	6.6	14.6
172	2	Fine-grained, gray, massive limestone, breaking with a smooth somewhat conchoidal fracture	7	8
		Dark-blue, semi-crystalline limestone; no sample taken	1	1

The following analyses show the chemical composition of the individual units described in the above section:

Analyses of Limestone, Southern Iron and Steel Company's Quarries

Sample No.	Unit No.	CaO	MgO	Fe_2O_3	SO_3	P_2O_5	SiO_2	Clay bases	Loss on ignition	Total
148	35	54.28	.50	.28	------	------	1.05	.42	43.47	100.00
149	34	53.98	.40	.32	------	------	.91	.37	44.02	100.00
150	33	53.46	.72	.50	------	------	1.57	.50	43.25	100.00
151	31	53.08	.82	.60	------	------	2.17	1.32	42.01	100.00
152	30	51.58	1.10	.82	------	------	3.72	.92	41.86	100.00
153	29	37.98	3.08	4.86	------	------	14.88	3.19	36.01	100.00
154	28	51.50	.40	1.22	------	------	4.50	.98	41.40	100.00
155	26	53.46	.46	.64	------	------	2.33	.41	42.70	100.00
156	25	51.60	.67	.84	------	------	4.27	.95	41.67	100.00
157	24	53.06	1.00	.66	------	------	1.70	.73	42.85	100.00
158	23	54.30	.22	.30	------	------	1.77	.43	42.98	100.00
159	22	53.84	.40	.32	------	------	1.55	.45	43.44	100.00
160	21	53.70	.72	.58	------	------	1.20	.40	43.40	100.00
161	20	54.04	.30	.82	------	------	1.46	.37	43.01	100.00
162	19	46.92	.28	2.32	------	------	10.01	1.77	38.70	100.00
163	18	52.90	.24	.92	.00	.01	3.00	1.21	41.72	100.00
164	17	52.46	.54	1.00	.00	tr.	3.40	1.20	41.40	100.00
165	15	52.90	.52	.46	.00	tr.	2.80	1.12	42.20	100.00
166	14	53.92	.44	1.40	.00	.01	1.20	.90	42.13	100.00
167	13	53.32	.32	1.72	tr.	tr.	1.40	.92	42.32	100.00

Analyses of Limestone, Southern Iron and Steel Company's Quarries—Continued

Sample No.	Unit No.	CaO	MgO	Fe_2O_3	SO_3	P_2O_5	SiO_2	Clay bases	Loss on ignition	Total
168	11	54.38	.12	.90	.00	tr.	1.20	.64	42.76	100.00
169	10	53.82	.35	.24	------	------	1.70	.50	43.39	100.00
170	7, 6, 5	52.44	.56	.88	------	------	2.48	.80	42.84	100.00
171	3	52.88	1.10	.86	------	------	1.80	.58	42.78	100.00
172	2	33.06	13.90	2.22	------	------	4.22	1.59	45.01	100.00

The shales on this property are contained in the Rockwood formation. It is not always easy to tell at just what stratigraphic point the exposures occur on account of the folding of the rocks and the poor exposures. Some heavy-bedded yellowish-brown sandstones are found near the base of the formation, together with a number of thin beds of limestone interstratified with the shales.

The following analyses show the composition of the Rockwood shales in Johnson's Crook:

Analyses of Shales, Southern Iron and Steel Company's Property

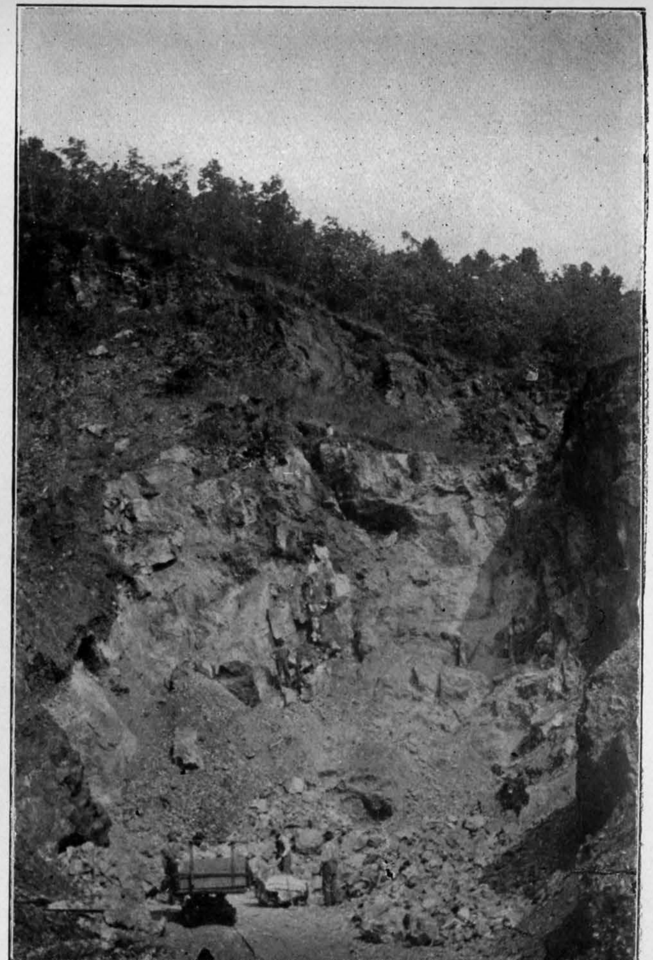
Sample No.	173[1]	174[2]	175[3]	176	177
Moisture at 100° C	.62	.52	------	------	------
Loss on ignition	10.40	9.16	------	------	------
Lime (CaO)	tr.	.10	2.00	1.66	1.34
Magnesia (MgO)	1.70	2.00	------	------	------
Alumina (Al_2O_3)	19.88	20.50	21.63	21.50	22.00
Ferric oxide (Fe_2O_3)	8.74	8.40	6.77	7.50	7.80
Titanium dioxide (TiO_2)	.92	------	------	------	------
Silica (SiO_2)	55.69	55.42	62.80	62.40	64.20
	97.95	96.10	93.20	93.06	95.34

[1]Taken over 12 feet of olive green shale exposed on the north side of the tram road between the crusher and Mine No. 2.

[2]Taken immediately above the opening of Mine No. 2, and consists of olive green shale. The exposure contains some interbedded sandstones and limestones, but these were not sampled.

[3]Samples Nos. 175, 176 and 177 were taken by H. S. Geismer, at that time manager of the Southern Steel Company, in the Chattanooga district. No. 175 was obtained from the upper shales of Rising Fawn mine No. 1, No. 176 from the middle shale of the ore, and No. 177 from the lower layer of shale in the ore bed. These shales can be used as a mix with limestone in the manufacture of Portland cement.

A. BANGOR LIMESTONE, LOWER QUARRY OF SOUTHERN IRON AND STEEL COMPANY, 1 MILE NORTHEAST OF RISING FAWN, DADE COUNTY, GEORGIA



B. KNOX DOLOMITE. A SECTION OF QUARRY, LADD LIME COMPANY, NEAR CARTERSVILLE, BARTOW COUNTY, GEORGIA.

Four miles northeast of Rising Fawn (Map location 7 D).—Four miles northeast of Rising Fawn along the Johnsons Crook road on the west side of Lookout Mountain, the upper heavy-bedded and massive brown sandstone of the Lookout formation forms the crest of the mountain, beneath which occur brown, red, and green shales with some interbedded thin and heavy-bedded sandstones at the base of the formation.

The Bangor formation contains some vari-colored shales (Pennington) at the top, beneath which occur grayish-blue, heavey-bedded limestones which are largely concealed by the float from the overlying formation.

The following section begins at the fork of the road at the top of the mountain and extends to the bottom of the mountain:

Section, Johnsons Crook Road, West Side of Lookout Mountain

Sample No.	Unit No.	Description of Units	Thickness feet	Total Thickness feet
	7	Heavy-bedded brown sandstone	7	892
178	6	Greenish-brown shales; red and green argillaceous shale at the bottom	65	885
	5	Argillaceous red and green shales	60	820
	4	Greenish-brown shale with some heavy beds of sandstone at the top and bottom	50	760
179	3	Argillaceous red and green shale; partially concealed	60	710
	2	Concealed	30	650
	1	Blue limestone; largely concealed	620	620
		Bottom of mountain	0	0

The following analyses show the composition of the shales overlying the Bangor limestone:

Analyses of Shale, Johnsons Crook Road, West Side Lookout Mountain

Sample	178	179
Unit No.	6	3
Moisture at 100° C.	.56	.52
Loss on ignition	4.28	5.80
Soda (Na_2O) } Potash (K_2O)	2.53	-------
Lime (CaO)	.09	1.60
Magnesia (MgO)	1.14	1.24
Alumina (Al_2O_3)	13.33	15.51
Ferric oxide (Fe_2O_3)	6.05	6.72
Titanium dioxide (TiO_2)	1.00	.81
Silica (SiO_2)	71.02	65.23
	100.00	97.43

Sitton Gulf (Map location 8 D).—Heavy-bedded, grayish-blue Bangor limestone is exposed in Sitton Gulf where it extends from the base of the mountain to a vertical height of 525 feet.

The following analysis shows the composition of an average sample taken over the entire exposure:

Analysis of Limestone, Sitton Gulf

(Sample No. 180)

Lime (CaO)	55.06
Magnesia (MgO)	.05
Ferric oxide (Fe_2O_3)	.38
Sulphur trioxide (SO_3)	.00
Phosphorus pentoxide (P_2O_5)	....
Silica (SiO_2)	.90
Clay bases	.35
Loss on ignition	43.26
	100.00

Two miles east of Trenton (Map location 9 D).—The property of G. W. Morrison is located about two miles east of Trenton. The heavy-bedded, grayish-blue limestones of the Bangor formation are exposed from the base of the formation at its contact with the Fort Payne chert for a vertical height of 580 feet.

Section, Top to Bottom, Two Miles East of Trenton

Sample No.	Unit No.	Description of Units	Thickness feet	Total Thickness feet
181	4	Fine-grained, dark-blue limestone, in places earthy and crinoidal	150	580
182	3	Dark-blue, heavy-bedded, high-calcium limestone	100	430
183	2	Dark-blue, fine-grained, crinoidal limestone; some quartz excretions are found 90 feet below the top of the unit	130	330
	1	Heavy-bedded, dark-blue and gray cherty limestone	200	200
		Fort Payne chert		

The following analyses show the composition of the units described above:

Analyses of Limestone Two Miles East of Trenton

Sample No.	181	182	183
Unit No.	4	3	2
Lime (CaO)	52.80	54.44	53.22
Magnesia (MgO)	.30	.20	1.12
Ferric oxide (Fe_2O_3)	1.14	.16	.48
Sulphur trioxide (SO_3)	tr.	.00	--------
Phosphorus pentoxide (P_2O_5)	tr.	tr.	--------
Silica (SiO_2)	2.01	1.02	2.15
Clay bases	1.04	.43	.60
Loss on ignition	42.71	43.75	43.43
	100.00	100.00	100.00

Two and one-half miles southwest of Trenton (Map location 10 D.)—Two and one-half miles southwest of Trenton along the Higdon-Trenton public road on the east side of Sand Mountain the upper massive limestone of the Lookout formation is well exposed, while the underlying shales and sandstones of the same formation are largely concealed. The Bangor limestone is occasionally exposed, some beds being argillaceous, others dolomitic and still others high-calcium.

The section from the top to the bottom of the mountain is as follows:

Section 2 1/2 Miles Southwest of Trenton

Sample No.	Unit No.	Description of Units	Thickness feet	Total Thickness feet
	7	Sandstone	100	618
	6	Sandstones and shales interbedded; largely concealed	210	518
184	5	Blue limestone; largely concealed	40	308
185	4	Blue limestone	10	268
	3	Cherty limestone	8	258
186	2	Blue limestone	200	250
	1	Blue limestone; largely concealed	50	50
		Level of valley road	0	0

The following analyses show the composition of the beds described in the above section:

Analyses of Limestone 2 1/2 Miles Southwest of Trenton

Sample No.	184	185	186
Unit No.	5	4	2
Lime (CaO)	49.52	53.60	45.92
Magnesia (MgO)	.62	.60	1.16
Ferric oxide (Fe_2O_3)	1.82	.64	2.98
Silica (SiO_2)	3.64	1.74	7.75
Clay bases	.73	.55	3.21
Loss on ignition	43.67	42.87	38.98
	100.00	100.00	100.00

Two and one-half miles northwest of New England (Map location 11 D).—Two and one-half miles northwest of New England along the Slago Cove road portions of the Bangor limestone and the Lookout formation are exposed. Interbedded, high-calcium and magnesian limestones of the Bangor formation extend from the base of the mountain to a height of 170 feet. Chert is found throughout many beds of the limestone and the abundance of this impurity will probably prevent the economic development of the limestone at this point. Shales of the Bangor and the Lookout formations overlie the limestone.

Analyses of Limestone and Shale 2 1/2 Miles Northwest of New England

Sample No.	187[1]	188[2]
Moisture at 100° C		67.
Loss on ignition	42.61	7.21
Lime (CaO)	53.86	tr.
Magnesia (MgO)	.12	1.00
Alumina (Al_2O_3)		17.82
Ferric oxide (Fe_2O_3)		7.39
Silica (SiO_2)	2.11	62.87
Sulphur trioxide (SO_3)	.62	
Phosphorus pentoxide (P_2O_5)	tr.	
Titanium dioxide (TiO_2)		.99
Clay bases	.68	
	100.00	97.95

Three miles north of New England (Map location 12 D).—Three miles north of New England and on the west side of a spur of Sand Mountain the heavy-bedded limestones of the Bangor formation are exposed over a vertical height of about 280 feet. Immediately above the limestones occur green and yellowish-brown shales which are largely exposed over a vertical height of 220 feet.

Section from Top to Bottom, 3 Miles North of New England

Sample No.	Unit No.	Description of Units	Thickness feet	Total Thickness feet
189	5	Yellowish-green and brownish-green shale	216.7	492.5
	4	Largely concealed; underlain by limestone	59.1	275.8
190	3	Heavy-bedded, bluish-gray limestone, with some beds of crinoidal limestone and clayey beds in the upper portion	78.8	216.7
191	2	Heavy-bedded, grayish-blue limestone; considerable loose chert at the bottom	98.5	137.9
192	1	Heavy-bedded, grayish-blue limestone with chert	39.4	39.4
		Base of the mountain	0	0

[1]Average composition of the limestone.

[2]Average composition of the dark brown carbonaceous shale immediately above the basal sandstone of the Lookout formation.

The following analyses show the composition of the units described in the above section:

Analyses of Limestone and Shale 3 Miles North of New England

Sample No.	189	190	191	192
Unit No.	5	3	2	1
Moisture at 100° C	.31			
Loss on ignition	7.06	41.61	43.30	43.04
Lime (CaO)	.08	52.00	53.20	52.90
Magnesia (MgO)	.98	.88	.62	.67
Alumina (Al_2O_3)	16.24			
Ferric oxide (Fe_2O_3)	6.38	1.32	.46	.58
Silica (SiO_2)	65.17	2.55	1.96	1.90
Sulphur trioxide (SO_3)				.00
Phosphorus pentoxide (P_2O_5)				tr.
Titanium dioxide (TiO_2)	.92			
Clay bases		1.64	.46	.91
	97.14	100.00	100.00	100.00

One and one-half miles northwest of Trenton (Map location 13 D). —At a point 1½ miles northwest of Trenton and along the White Oak Gap road the Lookout and Bangor formations are well exposed. The massive brown sandstone of the Lookout formation forms the crest of the mountain, beneath which are the interbedded sandstones and shales of the same formation. The Bangor limestones underlie the Lookout shales, but are poorly exposed. A large number of argillaceous and dark blue amorphous limestones somewhat high in magnesia are interbedded with the high-calcium stone. There is an extensive overburden of sandstone and shale scattered over the mountain side from the top to the bottom. The argillaceous beds and those high in magnesia are usually concealed. The strike is N. 27° E., and the dip 10° SE. The section begins at the top of the mountain and extends to the top of the Fort Payne chert.

Section 1 1/2 Miles Northwest of Trenton

Sample No.	Unit No.	Description of Units	Thickness feet	Total Thickness feet
	10	Heavy-bedded and massive brown sandstone	21.6	743.5
	9	Sandy grayish-brown shale with laminae of limonite	37.4	721.9
	8	Coal and shale	4.9	684.5
	7	Shales with interstratified sandstones in the upper portion of the unit; largely concealed	315.2	679.6
	6	Blue limestone, almost entirely concealed	19.7	364.4
193	5	Dark-blue, fine-grained limestone with a two-foot bed of earthy limestone near the top	44.3	344.7
194	4	Dark-blue, fine-grained limestone	64	300.4
	3	Argillaceous and cherty limestone	19.7	236.4
	2	Argillaceous limestone; largely concealed	216.7	216.7
	1	Fort Payne chert		

The following analyses show the composition of the units described in the above section:

Analyses of Limestone 1 1/2 Miles Northwest of Trenton

Sample No.	193	194
Unit No.	5	4
Lime (CaO)	54.62	52.90
Magnesia (MgO)	.36	.82
Ferric oxide (Fe_2O_3)	.40	.90
Silica (SiO_2)	.86	1.80
Clay bases	.34	.54
Loss on ignition	43.42	43.04
	100.00	100.00

Two miles west of Rising Fawn (Map location 14 D).—The heavy-bedded, grayish-blue limestones of the Bangor formation are exposed at intervals on the west side of Fox Mountain from its base to a vertical height of 375 feet, two miles west of Rising Fawn. Many beds of this formation are concealed, so that it is impossible to determine from a sample anything more than their general physical and chemical character.

Section from Top to Bottom, 2 Miles West of Rising Fawn

Sample No.	Unit No.	Description of Units	Thickness feet	Total Thickness feet
	3	Base of heavy-bedded sandstone	----------	----------
	2	Concealed	400.9	775.9
195	1	Bangor limestone; upper beds somewhat argillaceous with some chert; lower portion largely concealed	375	375

Analysis of Limestone 2 Miles West of Rising Fawn

(SAMPLE NO. 195; UNIT NO. 1)

Lime (CaO)	54.44
Magnesia (MgO)	.12
Ferric oxide (Fe_2O_3)	.56
Silica (SiO_2)	1.38
Clay bases	.57
Loss on ignition	42.93
	100.00

Proctors Bluff (Map location 15 D).—Proctors Bluff is located about one mile south of Rising Fawn on the west side of the Rising Fawn-Sulphur Springs road about three-fourths mile west of the Alabama Great Southern Railroad. The limestones of the Bangor formation are exposed over a thickness of about 100 feet. The lower portion of the exposure consists of limestones of light-blue to gray and dark-blue color and of variable physical character, while the upper portion is a more uniform massive, grayish-blue limestone. The strata lie practically level at this point.

Section from Top to Bottom, Proctors Bluff

Sample No.	Unit No.	Description of Units	Thickness feet	Total Thickness feet
		Top of bluff		
196	8	Grayish-blue and dark-blue, heavy-bedded and massive limestone	41.6	102.7
197	7	Grayish-blue to dark-blue heavy-bedded and massive limestone	40	61.1
198	6	Gray to grayish-blue, heavy-bedded amorphous limestone	5.1	21.1
199	5	Fine-grained, dark-blue, heavy-bedded and massive limestone, containing some scattered chert in the lower half	2	16
	4	Coralline limestone	2.7	14
	3	Heavy-bedded and massive grayish-blue somewhat semi-crystalline limestone	2.2	11.3
200	2	Fine-grained, dark-blue, heavy-bedded and massive limestone; crinoids, *spirifer* sp., and other brachiapods are found	3.4	9.1
201	1	Dark-blue, fine-grained massive and heavy-bedded limestone with some crinoids and cup corals	5.7	5.7
		Base of bluff	0	0

The following analyses show the composition of the units described in the above section:

Analyses of Limestone, Proctors Bluff

Sample No.	196	197	198	199	200	201
Unit No.	8	7	6	3,4,5,	2	1
Lime (CaO)	52.18	53.92	52.56	38.26	38.40	53.32
Magnesia (MgO)	1.02	.44	.86	7.60	6.52	1.05
Ferric oxide (Fe_2O_3)	1.18	1.40	.74	.82	1.66	.34
Sulphur trioxide (SO_3)			.01	.01	.03	.00
Phos. pentoxide (P_2O_5)			.02	.01	.02	.01
Silica (SiO_2)	1.98	1.20	3.02	11.51	8.71	1.62
Clay bases	.82	.92	1.06	3.10	4.83	.43
Loss on ignition	42.82	42.12	41.73	38.69	39.83	43.23
	100.00	100.00	100.00	100.00	100.00	100.00

Four miles southwest of Trenton (Map location 16 D).—Four miles southwest of Trenton and about 1¼ miles east of the Georgia-Alabama line the Bangor limestone is well exposed. The massive sandstone of the Lookout formation forms the crest of the mountain, beneath which occurs the thin-bedded sandstones and shales of the same formation. The Bangor limestones are exposed for a vertical height of 330 feet. The upper portion of the formation contains many beds of argillaceous impure limestones, while the lower portion is a high-calcium stone.

Section from Top to Bottom, 4 Miles Southwest of Trenton

Sample No.	Unit No.	Description of Units	Thickness feet	Total Thickness feet
	6	Shales		
	5	Argillaceous limestone	10	330.2
	4	Arenaceous brown shales	10	320.2
202	3	High-calcium limestone, (six feet of hard siliceous earthy limestone at the bottom of this unit not sampled)	52.2	310.2
203	2	Blue limestone	228	258
	1	Occasional exposures of blue limestone	30	30

The following analyses show the chemical character of units 2 and 3 in the above section:

Analyses of Limestone 4 Miles Southwest of Trenton

Sample No.	202	203
Unit No.	3	2
Lime (CaO)	47.24	53.66
Magnesia (MgO)	3.90	.80
Ferric oxide (Fe_2O_3)	2.12	.44
Silica (SiO_2)	1.42	1.20
Clay bases	2.66	.44
Loss on ignition	42.66	43.46
	100.00	100.00

WALKER COUNTY

GEOLOGY

Connasauga Shales and Limestones

The shales of this formation are yellowish-green or yellow and always argillaceous. The silica-alumina ratio is too low in the shales for their use in the manufacture of Portland cement. Limestones are interstratified with the shales. The argillaceous character of these limestones, together with their occurrence in thin beds, makes them unattractive for commercial use.

Knox Dolomite

The Knox dolomite is exposed only in the upper portion of the formation and the abundance of chert which is always present usually prevents the quarrying of it for any use, other than road metal and ballast. The high content of magnesia prevents its use in the manufacture of Portland cement.

Chickamauga Formation

The Chickamauga formation in Taylor Ridge and to the east of this ridge consists essentially of vari-colored shales with interbedded argillaceous limestones, while to the west of Taylor Ridge the formation consists essentially of thin bedded, blue, argillaceous limestones with many beds of high-calcium stone. The limestones to the west of Taylor Ridge are suitable in many localities for use in the manufacture of Portland cement. These limestones are at present extensively quarried for use as a building stone. On account of the general argillaceous character of the limestones they are not attractive for the manufacture of lime.

Rockwood Formation

The Rockwood formation in Taylor Ridge and to the east of Taylor Ridge consists of sandstones and interbedded shales. The shales are so intimately interstratified with the sandstones that their commercial development for use in the manufacture of Portland cement is not possible. The sandstones are not so numerous to the west of Taylor Ridge and when they are absent over any considerable stratigraphic thickness the shales fulfill all the requirements for use in the manufacture of cement.

Floyd Formation

The Floyd formation occupies only a small area in West Armuchee Valley. The beds lie almost level and are exposed at only a few places. The limestone is a high-calcium stone and can be used locally for the burning of lime or for road material; however, the conditions affecting development are likely to prevent the use of this limestone in the manufacture of cement in this county.

Bangor Formation

The Bangor formation consists of both limestones and shales. The shales which lie immediately above the limestones are yellowish-green, yellow, and red, and somewhat argillaceous. They vary in thickness from a few feet to several hundred feet.

The limestones of the formation attain their greatest thickness in Pigeon Mountain where they are exposed for more than 800 stratigraphic feet. Where the general conditions which affect their development are satisfactory these limestones can be won for commercial lime, road metal, ballast, concrete, fluxing stone, cement, etc., and the highly crystalline beds for a building stone.

DESCRIPTION OF INDIVIDUAL LOCALITIES

The Chickamauga Cement Company (Map location 1 W).—The plant and quarries of the Chickamauga Cement Company are located at Rossville, three-fourths mile south of the Georgia-Tennessee line, directly on the Central of Georgia Railway.

In 1900 W. P. D. Moross found at this point several strata of red argillaceous limestone above and beneath which occur blue and bluish-gray limestone. When the reddish-brown argillaceous limestone is mixed with the blue and bluish-gray limestone in the proper proportions and subsequently burned and ground it results in a Natural cement. Mr. Moross interested Uriah Cummings, of New York, in this property, who organized the Chickamauga Cement Company in 1901, incorporating it under the laws of Connecticut with W. P. D. Moross, President and Treasurer.

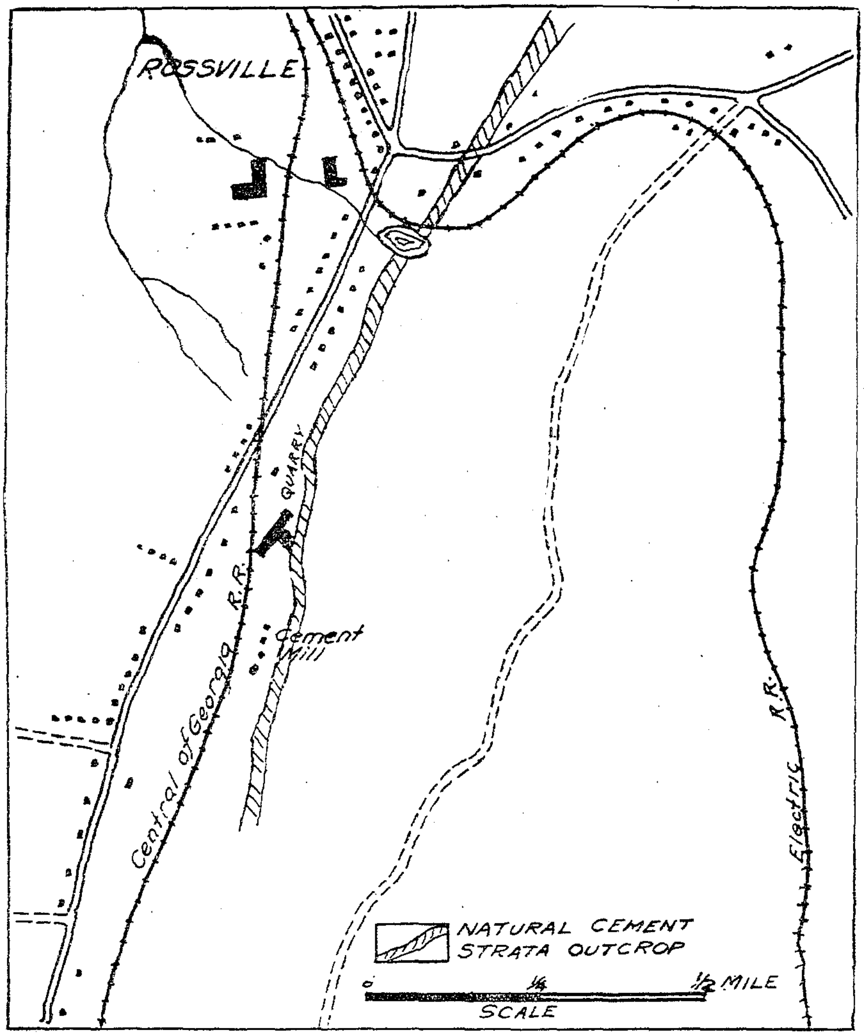


FIG. 6.—MAP SHOWING THE NATURAL CEMENT OUTCROP IN THE VICINITY OF ROSSVILLE, GA.

GEOLOGIC RELATIONS

The calcareous materials used at this point in the manufacture of natural cement and hydrated lime occur in the Chickamauga formation. The calcareous materials are of two kinds: a reddish-brown argillaceous limestone, "cement rock," and blue to gray, hard, thin-bedded limestones containing as much as 10 per cent. of silica, alumina and alkalies, with a very low content of iron oxide.

The Chickamauga formation in this vicinity forms a V-shaped valley with the apex of the "V" pointing southward. It is underlain at this point by the Knox dolomite. The reddish-brown argillaceous rock is won by underground mining, while the blue and bluish-gray limestone is quarried in open pit. The strike is N. 14° E., and the dip is 10° SE.

CONDITIONS AFFECTING DEVELOPMENT

The outcrops in the valley are somewhat numerous and extend in the general direction of the strike of the rock. Differences in the chemical composition and physical character of the rock cause slight variations in the topography of this valley-making formation. The exposures above water level seldom reach a height of more than fifteen feet so that in any extensive development quarries would necessarily extend to a considerable depth below water level. The formation varies in its lithologic character across the bedding, that is, from east to west and is more argillaceous to the east of the main stratum of "cement rock" and more calcareous to the west of this stratum. In order to quarry material of similar lithologic and chemical character the development of quarries must be in a northeast and southwest direction.

The overburden consists of a thin residual clay soil derived from the underlying limestone. The property is made accessible by the Central of Georgia Railway and is only about fifteen miles from the coal fields of northwest Georgia.

The following section from top to bottom shows the variations of the several beds of stone exposed at the quarries:

Section Chickamauga Cement Quarries

Sample No.	Unit No.	Description of Units	Thickness feet	Total Thickness feet
	18	Earthy, drab-colored, thin-bedded, argillaceous limestone	1.4	57.5
	17	Soft yellowish-green fire clay	.2	56.1

Section Chickamauga Cement Quarries—Continued

Sample No.	Unit No.	Description of Units	Thickness feet	Total Thickness feet
	16	Earthy drab-colored limestone grading into a reddish-brown argillaceous limestone	1	55.9
203	15	Reddish-brown argillaceous limestone	1.8	54.9
	14	Reddish-brown argillaceous limestone with seams of interbedded gray to green argillaceous rock	1.1	53.1
	13	Hard gray limestone containing considerable crystalized calcite. (This unit is discarded in cement manufacture and is not included in the sample taken for analysis)	.5	52.1
	12	Reddish-brown argillaceous limestone with occasional interbedded thin layers of green argillaceous rock. (A thin seam of gray limestone forms the base of the "cement rock")	2.3	51.6
	11	Thin-bedded, impure argillaceous limestone with a bed of fire clay about two inches thick	12.7	49.3
	10	Brown clay becoming more calcareous towards the top	3	36.6
	9	Grayish-blue argillaceous limestone	1.2	33.6
	8	Brown to dove colored argillaceous limestone	1	32.4
204	7	Brown calcareous clay	2.1	31.4
	6	Drab-colored clay with thin beds of drab-colored limestone at the top and bottom	1.5	29.3
204	5	Brown calcareous clay	1.3	27.8
	4	Brown clay with thin drab-colored argillaceous limestone at the top	1	26.5
204	3	Brown argillaceous limestone	2	25.5
	2	Green clay	3.5	23.5
205	1	Dark-blue to grayish-blue heavy-bedded limestone with many thin beds of limestone interbedded. This unit covers the entire stratigraphic thickness of the limestone exposed in the quarry. The whole exposure is intimately veined with secondary calcite	20	20

[1]Units 12-18 constitute the natural cement bed which is mined on this property.

The following analyses show the chemical composition of the raw materials used in the manufacture of the lime and natural cement:

Analyses of Raw Materials, Chickamauga Cement Company

Sample No.	203[1]	204	205	206[2]	207[3]	208[4]
Unit No.	12-16	3,5,7	1			
Lime (CaO)	33.80	25.56	47.98	41.70	42.70	42.85
Magnesia (MgO)	.45	1.02	1.25	1.80	1.40	1.41
Alumina (Al_2O_3)	--------	--------	--------	2.53	2.43	4.17
Ferric oxide (Fe_2O_3)	4.16	3.10	.96		.33	
Sulphur trioxide (SO_3)	.03	.00	.00	--------	--------	--------
Phos. pentoxide (P_2O_5)	.02	tr.	tr.	--------	--------	--------
Silica (SiO_2)	22.93	30.75	6.52	17.14	18.31	16.90
Clay bases	10.43	15.00	2.58	--------	--------	--------
Loss on ignition	28.18	24.57	40.71	36.83	34.83	34.67
	100.00	100.00	100.00	100.00	100.00	100.00

The twenty stratigraphic feet of limestone exposed in the quarry consisting of unit 1 in the section have been divided by Mr. Moross into three parts and are locally known as the three ledges. This has been done for convenience of knowing the chemical content of any portion quarried.

WINNING AND PREPARATION OF THE RAW MATERIALS

The limestone is quarried in an open pit, and is drilled and shot from place. The larger, more massive rock is then broken by means of sledge hammers into pieces of convenient size to be handled by the quarryman.

The "cement rock" is mined by following the stratum along both the dip and the strike down the slope. The limestone and "cement rock" are loaded on separate cars and elevated to the kilns by means of a pulley along an incline.

The limestone and "cement rock" are burned in separate kilns. There are four upright mixed feed kilns which have a daily capacity

[1]"Cement rock."
[2]Bottom ledge of quarry.
[3]Middle ledge of quarry.
[4]Upper ledge of quarry. Analyses furnished by W. P. D. Moross.

of 125 barrels each. Two kilns are used for burning the "cement rock" and two for burning the limestone.

MANUFACTURE OF HYDRATED LIME

The company began the manufacture of hydrated lime in 1906. The process of charging the kilns consisted in feeding alternately a carload of coal, then a carload of limestone. The gray limestone is calcined at a high temperature and is then drawn at the bottom of the kiln into wheelbarrows. A portion of water necessary for hydration is added and after the lime has been dumped more water is added to insure evenness of hydration. It usually takes about three days for the excess of lime to thoroughly hydrate; however, it depends largely on the weather conditions. The hydrated lime is pulverized in a tube mill to an impalpable powder, and then packed in bags for shipping. The trade name is "Hydrated Portland Lime."

Analyses[1] of "Hydrated Portland Lime"

	I	II
Calcium carbonate ($CaCO_3$)	80.77	81.87
Magnesium carbonate ($MgCO_3$)	4.83	3.09
Alumina (Al_2O_3) } Ferric oxide (Fe_2O_3) }	4.41	4.44
Silica (SiO_2)	6.32	6.74
	96.33	96.14

MANUFACTURE OF NATURAL CEMENT

The reddish-brown argillaceous limestone is burned to a temperature of 900-1,000 degrees C., so that the carbon dioxide is completely expelled and there is some combination of the argillaceous and calcareous materials. The calcined "cement rock" is drawn at the bottom of the kiln and mixed with the calcined limestone and hydraulic lime as follows:

2 car loads of calcined "cement rock."

2 car loads of calcined limestone.

1 car load of hydrated lime.

[1]Analyses by C. M. Clark, Chattanooga, Tenn., supplied by W. P. D. Moross.

This mixture is dumped into a Williams mill and crushed; then passes to a Krupp patent tube mill with a daily capacity of 500 barrels, where it is ground to such a fineness that 80 per cent. passes through a 100-mesh seive. It is then packed into bags or barrels and is ready for shipment. The trade name is "Dixie Rock."

Analysis[1] of "Dixie Rock" Cement

Calcium carbonate ($CaCO_3$)	60.89
Magnesium carbonate ($MgCO_3$)	3.35
Alumina (Al_2O_3)	6.20
Ferric oxide (Fe_2O_3)	1.99
Sulphur trioxide (SO_3)	.50
Silica (SiO_2)	25.89
	98.82

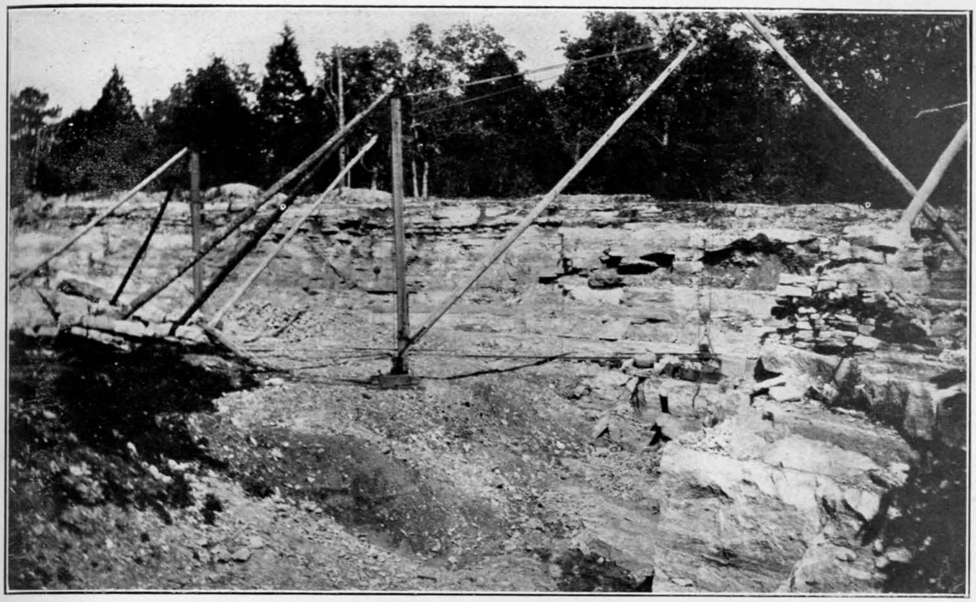
FINENESS

Fineness on No. 50 sieve	98.96%
" " " 100 "	93.85
" " " 200 "	89.51

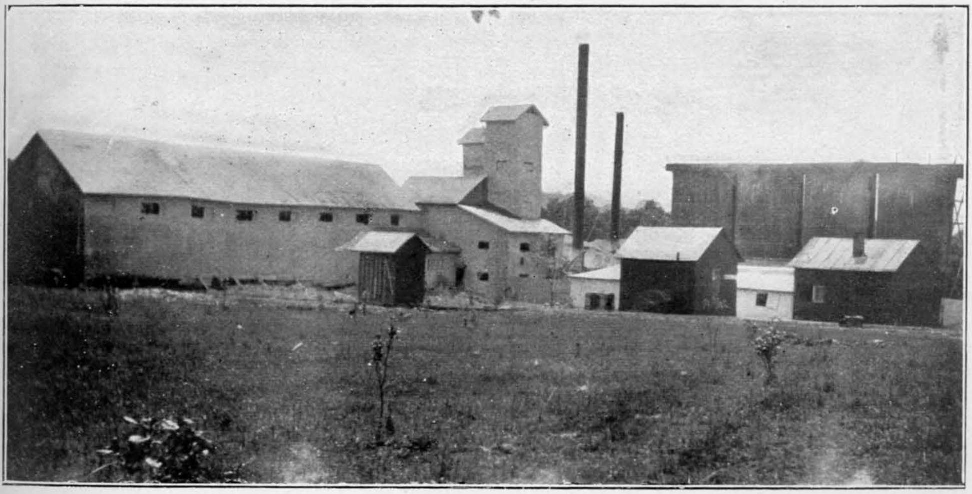
Time of set	Tensile strength[2] Age	Neat
Initial set 40° F. 1 hr. 30 min.	24 hrs.	97 lbs.
Final set 40° F. 3 to 4 hrs.	7 days.	180 lbs.
Initial set 80° F. 0 hr. 55 min.	28 days.	327 lbs.
Final set 80° F. 1 hr. 30 min.		

Trouth and Company's quarries (Map location 2 W).—The limestone quarries of Trouth and Company are located one-half mile southeast of Chickamauga station on the Central of Georgia Railway. The limestone is a part of the Chickamauga formation. It is both thin and heavy-bedded, which greatly facilitates procuring the stone of variable sizes for building purposes. The stone varies in color from a gray to dark blue and is fine-grained and crypto-crystalline throughout. It is quarried for building purposes only, and is used largely in the vicinity of Chattanooga for foundations, curbing, etc. Unit No. 3 in the following section has been used for fluxing purposes. A number of small quarries have been opened on the property. The strike is N. 15° E., and the dip is 8° SE.

[1]Analysis furnished by W. P. D. Moross.
[2]By Adam Wirth, chemist, City of New Orleans Testing Laboratory.



A. TROUTH AND COMPANY'S QUARRY, CHICKAMAUGA LIMESTONE, NEAR CHICKAMAUGA STATION, SHOWING THE VARIABLE THICKNESS OF THE BEDDING, WALKER COUNTY, GEORGIA



B. LIME KILNS AND MILL OF THE CHICKAMAUGA CEMENT COMPANY, ROSSVILLE, WALKER COUNTY, GEORGIA

The following section was made in Quarry No. 1, known as the old quarry, to which runs switch No. 3 of the Central of Georgia Railway:

Section from Top to Bottom, Quarry No. 1, Trouth and Company Quarries

Sample No.	Unit No.	Description of Units	Thickness feet	Total Thickness feet
	5	Somewhat argillaceous badly weathered limestone, having the appearance of most of the exposed limestone of the Chickamauga; thin-bedded and somewhat earthy	6	34.8
209	4	Gray, somewhat heavy-bedded, fine-grained limestone	1.6	28.8
210	3	Dark-blue, fine-grained, somewhat heavy-bedded limestone; (has been used for fluxing)	6.5	27.2
211	2	Gray, fine-grained heavy-bedded argillaceous limestone becoming impure towards the bottom, attaining a shaly character and greenish color	5.1	20.7
212	1	Fine-grained gray to grayish-blue, heavy-bedded limestone	15.6	15.6

The following analyses show the composition of the individual beds described in the above section:

Analyses of Limestone, Quarry No. 1, Trouth and Company

Sample No.	209	210	211	212
Unit No.	4	3	2	1
Lime (CaO)	52.38	51.60	42.56	50.86
Magnesia (MgO)	1.32	.72	4.10	.90
Ferric oxide (Fe_2O_3)	.56	.88	1.74	.80
Sulphur trioxide (SO_2)	--------	--------	.02	--------
Phosphorus pentoxide (P_2O_5)	--------	--------	tr.	--------
Silica (SiO_2)	1.88	4.28	9.40	2.58
Clay bases	1.32	1.40	4.10	1.44
Loss on ignition	42.54	41.12	38.08	43.42
	100.00	100.00	100.00	100.00

Catlett Gap road (Map location 3 W).—The limestones of the Chickamauga formation are exposed at a point several hundred feet east of Dry Creek, about 3 miles northwest of Lafayette. The lower portion of the formation consists essentially of thin-bedded argillaceous limestone. These beds were not sampled on account of their variable character. The upper 129 feet of the limestone, covering a horizontal distance of 300 feet along the road, is made up of thin-bedded, blue, fine-grained, high-calcium stone. The section from top to bottom is as follows:

Section, Catlett Gap Road

Sample No.	Unit No.	Description of Units	Thickness feet	Total Thickness feet
213	8	Blue to dark-blue, fine-grained limestone	108	323.4
	7	Dark grayish-blue to dark-blue limestone	21.6	215.4
	6	Largely concealed; and occasional outcrop of argillaceous blue limestone	76.3	193.3
	5	Concealed	23.5	117.5
	4	Thin-bedded argillaceous blue, gray, and pink limestone, varying greatly in lithologic character, some chert	47	94
	3	Concealed	18.8	47
	2	Light bluish-gray limestone	4.7	28.2
	1	Concealed	23.5	23.5
		Knox dolomite. (Horizontal distance from unit to the intersection of Catlett Gap and Dry Creek roads 800 feet)	0	0

The following analysis shows the chemical character of units 7 and 8:

Analysis of Limestone, Catlett Gap Road
(Sample No. 213)

Lime (CaO)	52.04
Magnesia (MgO)	.30
Ferric oxide (Fe_2O_3)	.50
Silica (SiO_2)	5.63
Loss on ignition	41.53
	100.00

McLamorc Cove (Map location 4 W).—The limestones of the Chickamauga formation are exposed over a stratigraphic thickness of about 50 feet at a point 3½ miles south of Cedar Grove post office on the east side of the public road. The limestones are thin-bedded, grayish-blue to dark-blue in color and usually much weathered on the exposed surfaces. The limestone carries clayey impurities which are very pronounced on the weathered rock. *Bryozoa, brachiapods, gastropods* and other fossils are numerous.

The following analysis shows the composition of the limestone at this point:

Analysis of Limestone from McLamore Cove

(Sample No. 214)

Lime (CaO)	49.50
Magnesia (MgO)	.50
Ferric oxide (Fe_2O_3)	.48
Silica (SiO_2)	6.91
Clay bases	3.09
Loss on ignition	39.52
	100.00

Horine Development Company (Map location 5 W).—The property of the Horine Development Company consists of about 6,000 acres of valley and mountain land located about 25 miles south of Chattanooga, directly on the Tennessee, Alabama and Georgia Railroad and within two miles of the Central of Georgia Railway.

GEOLOGIC RELATIONS

The limestones on this property extend for more than a mile in length. They form a mountain with an average height of about 500 feet; however, near the southern end of the property, the limestones extend from the base of the mountain to a height of 800 feet. The limestone is the Bangor of upper Mississippian (lower Carboniferous) age. The sandstones of the Lookout formation cap the mountain immediately south of this property.

The mountain is a gentle syncline and the rocks lie almost horizontal along the east side of the mountain.

The following section shows the physical character of the limestone over the entire exposure:

Section, Horine Development Company, Pigeon Mountain

Sample No.	Unit No.	Description of Units	Thickness feet	Total Thickness feet
215	15	Bluish-gray, light and dark-blue, heavy bedded and massive limestone; the upper beds oölitic	100	770
216	14	Same as above	20	670
217	13	Oölitic and coarsely crystalline, heavy-bedded gray limestone	100	650
	12	Largely concealed; 20 feet above the base considerable chert	50	550
218	11	Gray, heavy-bedded semi-crystalline limestone	30	500
219	10	Semi-crystalline gray and grayish-blue heavy-bedded limestone; apex Blue Bird gap	30	470
220	9	Grayish-blue to gray somewhat crystalline heavy-bedded limestone; loose nodules of chert scattered over surface	40	440
221	8	Heavy-bedded gray to grayish-blue semi-crystalline limestone; in places crinoidal	20	400
222	7	Crinoidal grayish-blue heavy-bedded limestone; largely crystalline with some oölitic limestone at the base	50	380
	6	Largely concealed; argillaceous limestone with some interbedded arenaceous shale; Bryozoa and brachiapods in abundance	90	330
223	5	Gray heavy-bedded massive limestone, often oölitic	40	240
224	4	Semi-crystalline gray and grayish-blue limestone	90	200
225	3	Almost entirely concealed, with some argillaceous limestone; chert on the surface	40	110
226	2	Dark-blue, heavy-bedded limestone with some crinoidal limestone	20	70
227	1	Gray to grayish-blue fine-grained heavy bedded limestone; some chert at the base	50	50
		Base of the limestone	0	0

The following analyses show the chemical character of the individual units described in the above section:

Analysis of Limestone, Horine Development Company's Property

Sample No.	Unit No.	CaO	MgO	Fe_2O_3	SO_3	P_2O_5	SiO_2	Clay bases	Loss on ignition	Total
215	15	53.44	.20	.70	tr.	.02	2.00	------	43.64	100.00
216	14	52.30	.25	1.04	.04	.01	1.58	------	44.78	100.00
217	13	54.78	.42	.44	.00	.01	1.20	.58	42.57	100.00
218	11	52.18	2.60	.78	tr.	.01	1.04	1.00	42.39	100.00
219	10	53.64	.08	.18	.00	.01	1.10	.40	44.59	100.00
220	9	53.50	.10	.28	tr.	tr.	1.26	.50	44.36	100.00
221	8	55.04	.12	.14	.00	tr.	.36	.50	43.84	100.00
222	7	54.84	.10	.44	.00	tr.	.90	.46	43.26	100.00
223	5	54.42	.50	.24	.00	tr.	.88	.62	43.34	100.00
224	4	52.76	.40	.32	.01	.02	2.56	.78	43.15	100.00
225	3	29.60	2.00	4.54	.02	.03	29.44	6.28	28.11	100.00
226	2	52.72	1.22	1.02	tr.	.02	2.48	1.24	41.30	100.00
227[1]	1									

It will be observed in the above section that the stratigraphic units are large. It was recognized, of course, that it is absolutely necessary to confine the thickness over which the sample is taken to a few feet when the lithology of the limestone is variable. It was not deemed necessary at this point, because a study of the relation of lithology and chemical composition had already been made. The magnesian beds which are found in some localities in this formation could always be told by their conchoidal fracture and fine-grained amorphous character. The formation was divided into separate units whenever there was any noticeable change in the physical character of the limestone and the samples which correspond to these units were carefully taken from each foot of the rock exposed. The limestone is so uniform from the top to the bottom of the exposure that it is almost impossible to differentiate the beds except by their contained fossils, grade of crystallinity, and oölitic character.

CHEMICAL INTERPRETATION

Twelve of the thirteen samples show a very high content of lime, (CaO) averaging 53.56 per cent.; the magnesia (MgO) content is very

[1]Analysis misplaced.

low in all of the samples, being usually less than 1 per cent.; the ferric oxide (Fe_2O_3) is less than 1 per cent. in ten of the samples; silica (SiO_2) is usually less than 1.5 per cent.; sulphur trioxide (SO_3) and phosphorus pentoxide (P_2O_5) are present in such small quantities that they do not need to be considered.

CONDITIONS AFFECTING DEVELOPMENT

The limestones on this property extend for more than a mile in a northeast and southwest direction, being largely exposed from the base to the top of the mountain. There is no overburden except residual soil. The mountain has been terraced somewhat by erosion and the limestone is well exposed between these semi-level terraces paralleling its greatest length, which greatly facilitates the quarrying of the stone. Any number of quarries can be located on the mountain and worked parallel to its length as well as at right angles to this direction.

The shale on the Horine Development Company's property is described below in the section across Shinbone Ridge; the shale occurs in great quantity and is well suited for the manufacture of Portland cement.

Shinbone Ridge (Map location 6 W).—A section was made along the Blue Bird Gap road. The Rockwood formation at this point is made up of yellowish and olive-green arenaceous shales and thin-bedded sandstones. The sandstones are abundant in the upper portion of the formation while they are almost entirely absent in the lower portion. The object of this section is to show primarily the physical and chemical character of the whole exposure in order to ascertain just what portions might become available for use in the manufacture of Portland cement.

On account of the complex folding of the rocks it was thought advisable to present the horizontal extent of each unit and its equivalent stratigraphic thickness.

The section begins at the intersection of a spur track from the Alabama, Tennessee and Georgia Railroad and the Blue Bird Gap public road and geologically at the contact of the Devonian black shale and the Rockwood formation.

Section on Shinbone Ridge

Sample No.	Unit No.	Description of Units	Horizontal distance feet	Thickness feet
	20	Concealed	400	
	19	Olive-green shales with many beds of green and some soft brown sandstone	70	30.6
	18	Yellowish-green and red argillaceous shales with some thin bedded sandstones; light-brown fossiliferous sand stone at the bottom; *pentamerous* sp. abundant	170	43.8
	17	Concealed	370	115.4
	16	Shales, largely concealed	40	12.7
	15	Brown sandstone and arenaceous shale	40	10.9
	14	Shallow syncline of sandstone	60	3.5
	13	Yellowish-green shales, largely concealed	300	7.9
228	12	Olive-green and yellowish-green shale with some arenaceous splintery shale	200	91.2
	11	Concealed	210	147.8
	10	Shales, largely concealed	80	47.2
229	9	Olive-green and yellowish green shale	125	70.2
	8	Yellowish-green shale with some flaggy sandstones. Iron ore bed 16 inches thick at top	50	49.3
	7	Yellowish-green shales with some flaggy sandstones	70	56.7
	6	Concealed	230	179.9
	5	Yellowish-green shale and thin bedded flaggy sandstone. Shale somewhat red and brown on the weathered surface	70	68.2
230	4	Yellowish-green fissile somewhat arenaceous shale	100	72
	3	Concealed	250	93.5
	2	Arenaceous yellowish-green and olive-green shale	50	39.3
231	1	Yellowish-green and olive-green arenaceous somewhat hackly shale	100	97.8
		Rockwood-Chickamauga contact		

The following analyses show the chemical character of the beds sampled in the above section:

Analyses of Shale from Shinbone Ridge

Sample No.	228	229	230	231
Unit No.	12	9	4	1
Moisture at 100° C	.62	.71	.42	.47
Loss on ignition	7.40	6.41	5.05	7.20
Lime (CaO)	tr.	tr.	tr.	tr.
Magnesia (MgO)	.65	1.13	.91	1.37
Alumina (Al_2O_3)	20.59	23.00	17.95	18.82
Ferric oxide (Fe_2O_3)	8.74	8.06	7.39	8.40
Titanium dioxide (TiO_2)	.93	.90	1.08	.68
Silica (SiO_2)	56.80	58.53	64.48	60.17
	95.73	98.74	97.28	97.11

West side of Pigeon Mountain (Map location 7 W).—The Chattanooga and Rockwood shales are well exposed on the west side of Pigeon Mountain. The section described below begins at a point 255 feet above the intersection of the tram ore road and the Blue Bird Gap trail. The Chattanooga black shales have a thickness of 15 feet. The shales of the Rockwood formation contain many interstratified sandstones. The section begins at the top of the Devonian black shale and from top to bottom is as follows:

Section West Side Pigeon Mountain

Sample No.	Unit No.	Description of Units	Thickness feet	Total Thickness feet
232	7	Chattanooga black shales	15	255
	6	Rockwood shales; concealed	60	240
	5	Olive-green hackly arenaceous shale with many sandy layers. *Halysites* sp. occurs about 15 feet below the top of this unit	25	180
233	4	Olive-green and yellowish-green somewhat hackly arenaceous shale	15	155
	3	Thin-bedded gray and brown sandstones and interbedded hackly and fissile		

Section West Side Pigeon Mountain—Continued

Sample No.	Unit No.	Description of Units	Thickness feet	Total Thickness feet
		olive-green shales. About 10 feet below the top of this unit the sandstones are heavy-bedded	30	140
234	2	Olive-green, fissile shales practically free from sandstone	80	110
	1	Yellowish-green, interbedded shales and sandstones. At the bottom of this unit occurs heavy-bedded brown sandstones above which there is a bed of red ore; at the top of the unit there is a thin bed of red ore	30	30
		Intersection of Blue Bird Gap road. The section ends with the base of the Rockwood formation; however, the contact of the Rockwood and the underlying Chickamauga limestone is some distance to the west, due to the gentle dip of the rocks		

The following analyses show the chemical character of the units described in the above section:

Analyses of Shale, West Side of Pigeon Mountain

Sample No.	232	233	234
Unit No.	7	4	2
Moisture at 100° C	1.20	.42	.46
Loss on ignition	9.21	4.24	3.95
Lime (CaO)	.04	tr.	tr.
Magnesia (MgO)	.57	.90	1.20
Alumina (Al_2O_3)	17.13	18.20	26.36
Ferric oxide (Fe_2O_3)	5.04	6.38	7.39
Titanium dioxide (TiO_2)	.79	1.10	1.01
Silica (SiO_2)	61.27	69.26	59.40
	95.25	100.50	99.77

Two and one-half miles southwest of Copeland (Map location 8 W).—The yellowish and olive-green shales of the Rockwood formation occur at a point about one mile northeast of the Catlett Gap road, on the south side of a small tributary of Dry Creek. The shales contain a few beds of thin-bedded sandstone. They are exposed over a stratigraphic thickness of 30 to 40 feet and chemically satisfy all the requirements for use in the manufacture of Portland cement.

The following analysis shows the composition of the shales over the entire exposure:

Analysis of Shale 2 1/2 Miles Southwest of Copeland

(Sample No. 235)

Loss on ignition	5.44
Lime (CaO)	1.60
Magnesia (MgO)	1.50
Alumina (Al_2O_3)	18.29
Ferric oxide (Fe_2O_3)	6.63
Manganese (MnO)	.10
Titanium dioxide (TiO_2)	.92
Silica (SiO_2)	61.23
	95.71

Jackson property (Map location 9 W).—Limestone of the Floyd formation is found on the P. Jackson property about one mile southeast of Greenbush post office in West Armuchee Valley. The exposure occupies a vertical and stratigraphic thickness of about 40 feet and consists of dark-blue, heavy-bedded limestone, containing many brachiapods. The rocks lie practically level.

The following analysis shows the composition of the limestone at this point:

Analysis of Limestone from Jackson Property

(Sample No. 236)

Lime (CaO)	53.66
Magnesia (MgO)	.30
Ferric oxide (Fe_2O_3)	1.10
Sulphur trioxide (SO_3)	tr.
Phosphorus pentoxide (P_2O_5)	tr.
Silica (SiO_2)	.87
Potash (K_2O)	.08
Soda (Na_2O)	.19
Loss on ignition	43.80
	100.00

Brum property (Map location 10 W).—The limestones of the Bangor formation are found along the northern portion of Pigeon Mountain in the rear of the house of William Tatum. The stone is heavy-bedded and massive, gray to grayish-blue in color and contains a large amount of chert in the upper 80 feet of the exposure.

Section from Top to Bottom on Brum Property

Sample No.	Unit No.	Description of Unit	Thickness feet	Total Thickness feet
237	3	Heavy-bedded, grayish-blue limestone containing chert; chert omitted in sampling	80	194
238	2	Fine-grained, grayish-blue, heavy-bedded limestone; some cream colored fine-grained limestone interbedded	100	114
239	1	Gray somewhat fine-grained heavy-bedded limestone; crinoidal at base	14	14

The following analyses show the chemical composition of the units described above:

Analyses of Limestone from Brum Property

Sample No.	237	238	239
Unit No.	3	2	1
Lime (CaO)	54.60	30.88	52.56
Magnesia (MgO)	.08	11.90	.10
Ferric oxide (Fe_2O_3)	.26	2.72	.76
Silica (SiO_2)	1.08	13.24	2.86
Clay bases	.28	2.88	1.40
Loss on ignition	43.70	38.38	42.32
	100.00	100.00	100.00

Nickajack Gap road, east side of Lookout Mountain (Map location 11 W).—The Lookout formation is exposed on the Nickajack Gap road on the east side of Lookout Mountain. It is underlain by yellowish-green and dark-brown shales (Pennington) of the Bangor formation. The dark-blue limestone of the Bangor formation is almost entirely concealed. The Fort Payne chert forms the base of the mountain and underlies the Bangor limestone. The section from top to bottom is as follows:

Section Nickajack Gap Road, East Side of Lookout Mountain

Sample No.	Unit No.	Description of Units	Thickness feet	Total Thickness feet
		Base of massive sandstone of the Lookout formation		
	11	Largely concealed	18.1	597.5
240	10	Somewhat arenaceous and hackly brownish-green shale with a small amount of concretionary iron oxide	9	579.4
	9	Greenish-brown sandstone and interbedded green shale; only about 15 feet of rock exposed	45.3	570.4
	8	Arenaceous green shales with sandstone beds which are often heavy bedded and massive	126.8	525.1
241	7	Yellowish-green shales	9	398.3
242	6	Dark-green to greenish-black splitery shale, weathering to a somewhat fine hackly shale	15	389.3
	5	Yellowish-green shales with a bed of sandstone near the top	30	374.3
243	4	Reddish shale	10	344.3
244	3	Yellowish-green shale	45	334.3
	2	Largely concealed	45.3	289.3
	1	Concealed	244	244

The following analyses show the chemical composition of the units described in the above section:

Analyses of Shale, Nickajack Gap Road, East Side of Lookout Mountain

Sample No.	240	241	242	243	244
Unit No.	10	7	6	4	3
Moisture at 100° C	.54	.41	1.85	.51	.40
Loss on ignition	8.50	9.10	7.71	7.28	6.40
Soda and potash (Na_2O, K_2O)			2.49		
Lime (CaO)	.00	tr.	.32	.00	tr.
Magnesia (MgO)	1.53	.66	1.38	1.50	1.38
Alumina (Al_2O_3)	21.80	21.86	20.90	18.50	18.15
Ferric oxide (Fe_2O_3)	8.40	6.72	7.56	9.60	6.05
Titanium dioxide (TiO_2)	.90	.80	.96	.92	.82
Silica (SiO_2)	54.83	57.68	56.83	59.60	63.49
	96.50	97.23	100.00	97.91	96.69

McLamore Cove (Map location 12 W).—The grayish-blue limestones of the Bangor formation are found 4½ miles south of Cedar Grove post office, on the west side of McLamore Cove. The lower 230 feet of the exposure contains a large amount of chert, while the upper 120 feet contains little chert.

Analyses of Limestones from McLamore Cove

Sample No.	245	246
Lime (CaO)	53.28	51.36
Magnesia (MgO)	1.62	2.95
Ferric oxide (Fe_2O_3)	.40	.32
Silica (SiO_2)	1.62	1.72
Clay bases	.32	.34
Loss on ignition	42.76	43.31
	100.00	100.00

Dougherty Gap (Map location 13 W).—The sandstones and shales of the Lookout formation are well exposed along the roadside at the southern end of McLamore Cove in the Dougherty Gap. The shales of the Bangor formation are partly exposed, while the underlying Bangor limestones are largely concealed by the float derived from the overlying formations. The following general section was made along the road from the top to the bottom of the mountain:

Section Dougherty Gap

Sample No.	Unit No.	Description of Units	Thickness feet	Total Thickness feet
	6	Interbedded sandstones and shales	170	574
	5	Dark-blue carbonaceous shales	80	404
	4	Concealed	40	324
	3	Olive-green and yellowish-brown shales	170	284
247	2	Grayish-blue limestone	50	114
	1	Largely concealed limestone	64	64

Analysis of Limestone from Dougherty Gap

(Sample No. 248)

Lime (CaO)	53.78
Magnesia (MgO)	1.02
Ferric oxide (Fe_2O_3)	.42
Silica (SiO_2)	.96
Clay bases	.21
Loss on ignition	43.61
	100.00

Coulter property (Map location 14 W).—The property of T. S. Coulter is located on the west side of Pigeon Mountain in the extreme southeastern portion of McLamore Cove. The Bangor limestone is exposed over about 40 feet at a point about 200 feet southwest of the Coulter residence and consists of heavy-bedded, dark-blue limestone with some crinoidal limestone.

Analysis of Limestone on the Coulter Property

(Sample No. 249)

Lime (CaO)	49.80
Magnesia (MgO)	3.26
Ferric oxide (Fe_2O_3)	.74
Silica (SiO_2)	1.00
Clay bases	.68
Loss on ignition	44.52
	100.00

One mile southwest of Cedar Grove post office (Map location 15 W).—The Bangor limestone is exposed over a thickness of 57 stratigraphic feet at a point about one mile southwest of Cedar Grove post office, on the east side of Lookout Mountain. Many of the beds contain chert and on the surface are found excrescent quartz. The strike is N. 28° E., and the dip 15° NW.

The following analysis shows the composition of the limestone over the entire exposure:

Analysis of Limestone, One Mile Southwest of Cedar Grove

(Sample No. 250)

Lime (CaO)	53.00
Magnesia (MgO)	1.92
Ferric oxide (Fe_2O_3)	.36
Silica (SiO_2)	2.37
Clay bases	.57
Loss on ignition	41.78
	100.00

Bowers Gap (Map location 16 W).—The Bangor limestone is exposed at a point about 1½ miles due west of Cassandra on the mountain side just south of the Bowers Gap road. The limestone extends from the base of the mountain to a height of 316 feet, above which the rock is concealed for 311 feet. The Lookout sandstone is exposed over a thickness of 87 feet and forms the top of the mountain.

Section at Bowers Gap

Sample No.	Unit No.	Description of Units	Thickness feet	Total Thickness feet
	8	Sandstone and shales	87.6	715.5
	7	Concealed	311.6	627.9
	6	Largely concealed; an occasional outcrop of limestone	48.7	316.3
251	5	Fine-grained, heavy-bedded limestone with an occasional bed of semi-crystalline limestone	58.4	267.6
252	4	Inter-bedded, fine-grained and semi-crystalline heavy-bedded, grayish-blue and dark-blue limestone	58.4	209.2
253	3	Grayish-blue and dark-blue heavy-bedded limestone; some portions concealed	73	150.8
254	2	Dark-blue, somewhat fine-grained limestone	38.9	77.8
255	1	Heavy-bedded and massive, dull grayish-blue to dark-blue limestone, in places oölitic and containing an occasional bed of fine-grained limestone	38.9	38.9
		Base of mountain	0	0

The following analyses show the composition of the units described in the above section:

Analyses of Limestone from Bowers Gap

Sample No.	251	252	253	254	255
Unit No.	5	4	3	2	1
Lime (CaO)	52.24	54.26	54.50	55.48	54.94
Magnesia (MgO)	.87	.12	.08	.06	.08
Ferric oxide (Fe_2O_3)	.70	.42	.80	.62	.44
Sulphur trioxide (SO_3)		.00			.00
Phosphorus pentoxide (P_2O_5)		tr.			tr.
Silica (SiO_2)	1.82	.74	1.04	1.01	.72
Clay bases	.68	.36	.40	.60	.22
Loss on ignition	43.69	44.10	43.18	42.23	43.60
	100.00	100.00	100.00	100.00	100.00

One-half mile west of Cassandra (Map location 17 W).—The Rockwood shales are exposed from the top of the formation to the bottom at a point about one-half mile west of Cassandra along the Cassandra-Stevens Gap public road. The formation consists essentially of yellow and olive-green shale with many thin beds of sandstone. The strike is N. 20° E., and the dip 37° NW.

The section is here given.

Section One-Half Mile West of Cassandra

Sample No.	Unit No.	Description of Units	Thickness feet	Total Thickness feet
	14	Concealed; Silurian-Devonian contact	59.2	541.2
	13	Olive-green fissile argillaceous shale with an occasional bed of sandstone	41.4	482
	12	Concealed	10.8	440.6
	11	Olive-green shale with an occasional thin bed of sandstone	27.2	429.8
	10	Olive-green shale	27	402.6
	9	Concealed	54.4	375.4
	8	Concealed	32.6	321
	7	Olive-green shale with inter-bedded brown and green flaggy sandstone	27.2	288.4
	6	Olive-green shale. This unit contains several thin beds of soft red ore and and a bed of greenish-brown sandstone 6 inches thick at the top	59.4	261.2
	5	Olive-green fissile argillaceous shale containing thin beds of flaggy brown and green sandstone. The sandstone is not very abundant. Several thin beds of soft red ore 3 to 4 inches thick occur near the top	51.8	201.8
	4	Olive-green fissile argillaceous shale. About one foot below the top of this unit a thin bed of fossiliferous limestone occurs	49.9	150
	3	Olive-green fissile argillaceous shale containing a thin bed of fossilferous light-brown sandstone near the top	21.2	100.1
	2	Concealed	12.7	78.9
	1	Concealed, Silurian-Ordovician contact in this unit	66.2	66.2

One and onc-half miles northwest of Cassandra (Map location 18 W).—The Bangor limestone is exposed over a vertical thickness of 175 feet at a point 1½ miles northwest of Cassandra. The upper portion of the exposure is oölitic in places and contains some chert. The lower portion of the exposure is more uniform in physical character. The section from top to bottom is as follows:

Section 1 1/2 Miles Northwest of Cassandra

Sample No.	Unit No.	Description of Units	Thickness feet	Total Thickness feet
256	4	Heavy-bedded, dark-blue somewhat fine-grained limestone with interbedded gray oölitic and bluish-gray limestone	40	195
	3	Largely concealed, containing fragments of chert on the surface. Chert layer concealed	25	155
257	2	Bluish-gray, heavy-bedded limestone, in places exposed	70	130
	1	Somewhat fine-grained interbedded dark-blue and grayish-blue limestone	60	60

The following analyses show the composition of units 2 and 4 described in the above section:

Analyses of Limestone 1 1/2 Miles Northwest of Cassandra

Sample No.	256	257
Unit No.	4	2
Lime (CaO)	54.53	53.20
Magnesia (MgO)	.10	.40
Ferric oxide (Fe_2O_3)	.92	.68
Silica (SiO_2)	.96	2.42
Clay bases	.40	.66
Loss on ignition	43.09	42.64
	100.00	100.00

Southern Iron and Steel Company (Map location 19 W).—The property of the Southern Iron and Steel Company is located about one mile east of High Point on the east side of Lookout Mountain. A portion of the Rockmart formation and the Chattanooga black shale are exposed at the base of the mountain. The Fort Payne chert immediately overlies the Chatanooga black shale and is succeeded by the Bangor limestone.

Section Northeast of High Point, Southern Iron and Steel Company

Sample No.	Unit No.	Description of Units	Thickness feet	Total Thickness feet
		Top of limestone quarry		
258	8	Light-gray, fine-grained limestone	1.4	43.9
259	7	Heavy-bedded, fine-grained, grayish-blue limestone	14.1	42.5
260	6	Fine-grained, grayish-blue to dark blue limestone not so massive as the above unit; contains an occasional chert nodule	3.3	28.4
	5	Heavy-bedded to massive, bluish-gray limestone containing several beds of amorphous gray limestone intimately interbedded	13.8	25.1
261	4	Dark-blue, heavy-bedded limestone; largely crystalline, though not noticeably so megascopically	1.2	11.3
262	3	Fine-grained, heavy-bedded grayish-blue limestone	3.3	10.1
	2	Cherty and arenaceous grayish-blue limestone, in places approaching a sandstone in lithologic character and again becoming more calcareous	1	6.8
	1	Fine-grained, dark-blue and bluish-gray massive limestone containing chert nodules interspersed from top to bottom. In the lower portion of the unit the chert is in fairly distinct layers, while in the upper portion it is scattered throughout. Fourteen inches below the top of this unit occurs a two-inch layer of corals (cup corals). Below the massive cherty limestone a few feet of dark-blue limestone are exposed	5.8	5.8
		Base of quarry	0	0

The Chattanooga black shale and a portion of the underlying Rockwood shale are exposed at the base of the mountain. The shale exposed in the quarry consists of—

		Thickness feet
Sample No. 263	Chattanooga black shale....................	10.4
	Rockwood shale; gray to green clay shale...	15

The following analyses show the chemical composition of the individual units described in the above sections:

Analyses of Limestones and Shale, Southern Iron and Steel Company

Sample No. / Unit No.	258 / 8	259 / 7	260 / 6	261 / 4	262 / 3	263 / Shale
Moisture at 100° C	--------	--------	--------	--------	--------	.56
Loss on ignition	40.82	42.82	43.54	43.06	39.53	23.60
Lime (CaO)	29.46	54.50	51.18	54.80	49.08	.00
Magnesia (MgO)	15.92	.20	.40	.04	.56	1.26
Alumina (Al_2O_3)	--------	--------	--------	--------	--------	10.91
Ferric oxide (Fe_2O_3)	1.06	.66	.88	.48	.66	9.74
Silica (SiO_2)	9.86	1.20	3.38	1.08	8.02	48.73
Titanium dioxide (TiO_2)	--------	--------	--------	--------	--------	.77
Clay bases	2.88	.62	.62	.54	2.15	--------
	100.00	100.00	100.00	100.00	100.00	95.57

CATOOSA COUNTY

GEOLOGY

Rome Formation

The lower and middle portions of the Rome formation are largely composed of interstratified sandstones and shales. The abundance of these sandstones hinder the economic winning of the shales for use in the manufacture of cement. The upper portion of the formation consists essentially of shales with only a few interbedded sandstones. The shales will be found suitable at certain localities for use in the manufacture of cement; however, they are usually too high in alumina to be used without the admixture of free silica in the form of sand or with some other more highly siliceous shale or clay.

Connasauga Shales and Limestones

The limestones of this formation are thin-bedded and seldom reach a thickness of more than 100 feet. They are nearly always valley-forming and have only a small stratigraphic thickness, so that they are not attractive commercially for the manufacture of cement.

The shales are high in alumina and low in silica and can not be used alone for the manufacture of Portland cement.

Knox Dolomite

The Knox dolomite is exposed only in the upper portion of the formation. It consists of heavy and massive beds of gray, partly crystalline dolomite with many layers and nodules of chert. The high percentage of magnesia characterizing the dolomite prevents its use in the manufacture of Portland cement. The stone is being burnt into commercial lime at Hales quarry near Graysville. It is also suitable for ballast, concrete and many other crushed stone products.

Chickamauga Formation

The Chickamauga formation is made up of interstratified, vari-colored argillaceous shales and limestones in White Oak Mountain and Taylor Ridge. The formation consists almost entirely of thin-bedded blue limestones in the valley of Chickamauga Creek. These blue limestones usually carry a low percentage of magnesia and are at many places chemically suitable for use in the manufacture of cement. They are extensively quarried both in Georgia and Tennessee for use as a building stone.

Rockwood Formation

The Rockwood formation in this county consists essentially of interbedded sandstones and shales. The shales are so intimately interstratified with the sandstones that they are seldom commercially available for use in the manufacture of Portland cement.

Bangor Formation

The limestones of the Bangor formation immediately overlie the Fort Payne chert in Catoosa Ridge, just east of White Oak Mountain. They are heavy-bedded, grayish-blue to dark-blue high-calcium limestones and are chemically suitable for use in the manufacture of Portland cement. They will make a good lime, both for building and agricultural purposes and are also suitable for road metal, ballast, and other crushed stone products.

DESCRIPTION OF INDIVIDUAL LOCALITIES

Fort Oglethorpe well No. 5 (Map location 1 Ca).—The following section of a deep well at Fort Oglethorpe, Chickamauga Park, shows the lithologic character of the Chickamauga limestone and a portion of the Knox dolomite at that point:

Section from Top to Bottom Well No. 5, Ft. Oglethorpe, Ga.

Sample No.	Unit No.	Description of Units	Vertical feet	Total Vertical feet
264	29	Dark-grayish-blue limestone	50	50
265	28	Light-gray to grayish-blue limestone	50	100
266	27	Gray to grayish-blue limestone	400	500
	26	Dark-gray limestone	30	530
267	25	Dark-gray to grayish-black limestone	20	550
268	24	Grayish-black limestone, apparently somewhat siliceous	40	590
269	23	Ten feet of light-grayish-blue limestone, below which occurs ten feet of dark-grayish-blue limestone. The lower 20 feet is made up of dark-gray to black limestone	40	630
	22	Light-grayish-blue limestone	40	670
	21	Ten feet of grayish-black limestone,		
270	22	Light-grayish-blue limestone	40	670
	21	Ten feet of grayish-black limestone, beneath which occurs 20 feet of blueish-gray limestone. The lower 120 feet is made up of dark-gray to grayish-blue limestone	150	820
271	20	Dove-colored and gray limestone	30	850
272	19	Gray to grayish-blue argillaceous limestone	10	860
	18	Pinkish argillaceous limestone	10	870
273	17	Grayish-blue argillaceous limestone	30	900
	16	Ten feet of dark-gray limestone, beneath which occurs 20 feet of light-gray limestone, becoming very light light in color in the lower 10 feet	30	930
	15	Gray to grayish-blue argillaceous limestone	60	990

Section from Top to Bottom Well No. 5, Ft. Oglethorpe, Ga.—Cont'd

Sample No.	Unit No.	Description of Units	Vertical feet	Total Vertical feet
274	14	Gray limestone	80	1,070
	13	Gray limestone with some dove-colored limestone	20	1,090
275	12	Gray limestone	20	1,110
		Knox dolomite		
276	11	Gray dolomite	30	1,140
277	10	Gray dolomite	90	1,230
278	9	Gray somewhat cherty dolomite	40	1,270
279	8	White sandy dolomite	10	1,280
	7	Gray dolomite somewhat siliceous in the upper 10 feet	80	1,360
280	6	Gray dolomite, somewhat siliceous in the upper 40 feet	90	1,450
	5	Gray dolomite	70	1,520
281	4	Bluish-gray dolomite	30	1,550
282	3	Gray somewhat siliceous dolomite	100	1,650
283	2	Gray siliceous dolomite	100	1,750
284	1	Gray and white fine siliceous dolomite	110	1,860
		Bottom of well		

The following analyses show the composition of the units described in the above section:

Analysis of Limestone and Dolomite from Well No. 5, Ft. Oglethorpe, Ga.

Sample No.	Unit No.	CaO	MgO	Fe_2O_3	SO_3	P_2O_5	SiO_2	Clay bases	Loss on ignition	Total
264	29	42.00	2.85	3.16	.24	.03	11.20	5.10	35.42	100.00
265	28	30.60	.404	2.10	.10	.02	22.12	12.66	28.36	100.00
266	27, 26	47.46	3.20	.48	.02	tr.	6.13	2.13	40.58	100.00
267	25	48.42	3.80	.52	.00	tr.	3.44	1.88	41.94	100.00
268	24	49.86	5.28	.30	.03	.01	4.26	2.59	37.67	100.00
269	23	29.04	19.57	.40	.04	tr.	3.94	3.04	43.97	100.00
270	22, 21	40.64	3.50	1.86	.04	.01	17.73	------	36.22	100.00
271	20	32.90	7.00	1.60	.10	.03	15.11	8.61	34.65	100.00
272	19, 18	22.04	3.32	3.58	tr.	tr.	24.28	10.48	36.30	100.00

A. CONNASAUGA LIMESTONE. PORTION OF QUARRY OF THE GRAYSVILLE MINING AND MANUFACTURING COMPANY IMMEDIATELY WEST OF GRAYSVILLE, CATOOSA COUNTY, GEORGIA

B. KNOX DOLOMITE. EASTERN END OF QUARRIES OF GRAYSVILLE MINING AND MANUFACTURING COMPANY, EAST OF GRAYSVILLE, CATOOSA COUNTY, GEORGIA

Analysis of Limestone and Dolomite from Well No. 5, Ft. Oglethorpe, Ga.—Continued

Sample No.	Unit No	CaO	MgO	Fe_2O_3	SO_3	P_2O_5	SiO_2	Clay bases	Loss on ignition	Total
273	17, 16, 15	40.48	7.02	1.02	tr.	.01	8.20	3.52	39.75	100.00
274	14, 13	26.68	11.00	2.22	.02	.03	26.87	------	33.18	100.00
275	12	29.16	10.02	1.20	tr.	.01	21.20	.93	37.48	100.00
276	11	35.76	14.80	.76	.02	.01	2.47	1.42	44.76	100.00
277	10	37.76	13.10	.86	.02	tr.	3.12	1.51	43.43	100.00
278	9	28.78	7.02	1.12	.02	tr.	12.34	1.12	49.60	100.00
279	8, 7	34.82	11.75	.88	.08	.04	10.70	------	41.73	100.00
280	6, 5	38.64	11.00	.93	.04	.02	7.08	2.82	39.49	100.00
281	4	35.22	1.60	4.44	.08	.02	18.37	9.20	31.07	100.00
282	3	24.12	19.00	.98	.04	.02	15.98	------	39.86	100.00
283	2	29.34	15.90	1.06	.02	tr.	16.78	1.26	35.64	100.00
284	1	26.80	10.46	1.50	.02	.02	28.01	------	33.19	10.00

Graysville Mining and Manufacturing Company (Map location 2 Ca).—The quarries of the Graysville Mining and Manufacturing Company are located in the western portion of the town of Graysville and directly on the Western and Atlantic Railroad. John D. Gray, of Graysville, constructed a "ground hog" kiln at this point in 1869 to burn this stone in order to ascertain just what sort of lime it would produce. The lime was apparently satisfactory, for four kilns made of stone were immediately constructed. Mr. Gray sold the property in 1886 to a newly formed company organized by Alabama people, known as the Graysville Mining and Manufacturing Company. This company continued operations at this point until 1901, when they abandoned their workings and opened up quarries at a point one-half mile east of Graysville. During the same year M. M. Church, of Graysville, leased these new quarries and manufactured lime until 1910. The plant at present consists of two upright separate feed kilns with a daily capacity of 250 barrels. The lime was shipped both in bulk and in barrels, and was known as "pure white Catoosa lime." The stone used consists of both the Knox dolomite and the Connasauga limestone.

The Knox dolomite contains many beds of chert in the form of nodules and also in layers. The dolomite is heavy-bedded and massive, somewhat finely crystalline and of dark blue and light gray color.

The Connasauga limestone contains no chert, nor does it have the same massive appearance as the dolomite, both the color and lithologic character being pretty uniform throughout. It is a fine-grained amorphous limestone containing fragmentary remains of fossils, which in places are in considerable abundance, together with some few calcite stringers and thin lense-like argillaceous intercalations.

The Connasauga limestone was at one time used as a fluxing stone. The lime resulting from the burning of this stone is of a darker color than lime produced from the Knox dolomite, and is also a quicker setting lime.

The most northern quarry consisting of the Knox dolomite is designated quarry No. 1. The quarry located immediately north of the main public road and west of Graysville is made up of the Connasauga limestone and has been designated as quarry No. 2. The rocks are exposed over a vertical height of more than 100 feet in quarry No. 1, while its horizontal extent is not more than 20 feet. Quarry No. 2 has an average height of about 40 feet and extends along a horizontal distance of 450 feet.

The following sections show the physical character of the stone from top to bottom in these quarries:

Section Quarry No. 1, Graysville Mining and Manufacturing Company

Sample No.	Unit No.	Description of Units	Thickness feet	T tal Thickness feet
	30	Somewhat shaley gray thin-bedded dolomite	.6	458.8
	29	Grayish-white, heavy-bedded dolomite	4.5	458.2
	28	Thin-bedded gray dolomite	1	453.7
	27	Thin and heavy-bedded bluish-gray dolomite	5.5	452.7
	26	Arenaceous cherty gray dolomite (not sampled)	10	447.2
	25	White arenaceous dolomite (not sampled)	1	437.2
285	24	Arenaceous dolomite (not sampled)	1.7	436.2
	23	Dark-blue comparatively thin-bedded dolomite	1.4	434.5
	22	Cherty nodular grayish-blue dolomite	2	433.1
	21	Grayish-blue to gray heavy-bedded dolomite	5	431.1
	20	Gray dolomite, cherty at bottom	2.6	426.1
	19	Thin-bedded gray dolomite	1.7	423.5
	18	Cherty arenaceous gray heavy-bedded to massive dolomite	9.5	421.8
	17	Gray dolomite heavy-bedded at the top, massive at the bottom	11	412.3
	16	Gray dolomite	6	401.3
	15	Cherty gray dolomite	10.6	395.3
286	14	Massive gray to bluish-gray dolomite	5.4	384.7
	13	Gray massive dolomite	4.4	379.3
	12	Massive gray to bluish gray dolomite	9	374.9
	11	Dark-blue massive dolomite	2.4	365.9
	10	Heavy-bedded, grayish-blue dolomite	7	363.5
	9	Concealed. (Direction of traverse S. 40° W; horizontal distance 170 feet)	13	356.5
		Section quarry No. 2..		
287	8		36.7	343.5
288	7	Heavy-bedded and massive dark-blue and grayish-blue limestone		
289	6		76.7	260.1
290	5		51.1	183.4
291	4	Massive and heavy-bedded dark-blue and grayish-blue limestone. Fossils collected near the bottom in loose bowlders	20.4	132.3
292	3	Dark-blue and grayish-blue, massive		

Section Quarry No. 1, Graysville Mining and Mfg. Co.—Continued

Sample No.	Units No.	Description of Units	Thickness feet	Total Thickness feet
		and heavy-bedded limestone with some pyrite. Small amount of clayey intercalations and some small veined calcite near the top. The rock is somewhat honeycombed due to leaching	33.6	111.9
	2	Massive and heavy-bedded dark-blue fossiliferous limestone with small amount of pyrite	33.6	78.3
293	1	Massive and heavy-bedded dark-blue fossiliferous limestone made up largely of the remains of brachiapods and trilobites	44.7	44.7

The following analyses show the chemical character of the various units of the above sections:

Analyses of Limestone and Dolomite, Quarries of the Graysville Mining and Manufacturing Company

Sampl No.	Unit No.	CaO	MgO	Fe_2O_3	SO_3	P_2O_5	SiO_2	Clay bases	Loss on ignition	Total
285	19–30	31.02	16.00	1.52	.01	.02	5.86	3.0	42.57	100.00
286	10–18	25.60	16.00	2.60	.00	.01	15.40	2.86	37.53	100.00
287	8	47.16	3.82	.64	.02	.01	4.09	2.52	41.74	100.00
288	7	42.52	4.71	1.70	.01	.02	6.17	6.35	38.52	100.00
289	6	48.80	1.20	.92	.01	.01	6.20	1.87	40.99	100.00
290	5	50.58	1.30	1.00	.00	.01	2.82	2.72	41.57	100.00
291	4	49.00	2.10	.80	.00	.05	4.80	1.91	41.34	100.00
292	3	49.76	2.95	.62	.00	tr.	2.46	2.30	41.91	100.00
293	1–2	44.68	2.75	1.08	.00	.01	6.58	3.30	41.60	100.00

Both the Connasauga limestone and the Knox dolomite can be used in the manufacture of lime, for ballast, or for road metal. The percentage of lime is lower than desired and the percentage of magnesia is higher than desired in the Connasauga limestone at this point for use in the manufacture of cement. Dolomites contain too much magnesia for use in the manufacture of cements.

A. RED IRON ORE ON THE ROCKWOOD SHALES, PETERS PROPERTY, TAYLOR RIDGE, CHATTOOGA COUNTY, GEORGIA

B. CLOSE VIEW OF HALE QUARRY, SHOWING MASSIVE AND HEAVY-BEDDED KNOX DOLOMITE, CATOOSA COUNTY, GEORGIA

Another quarry of the Graysville Mining and Manufacturing Company is located one-half mile east of Graysville (map location 3 Ca). The following section from top to bottom begins at the most eastern exposure of the quarry. The strike is N. 15° E., and the dip 30° E.

Section One-Half Mile East of Graysville, Graysville Mining and Manufacturing Company's Quarry.

Samhle No.	Unit No.	Description of Units	Thickness feet	Total Thickness feet
294	10	Dark-bluish-gray somewhat cherty dolomite	5	35
	9	Grayish-blue to dark-blue dolomite almost free of chert	5	30
	8	Light-blue dolomite at the top becoming dark-blue towards the bottom. Chert layers abundant and parallel to the bedding	4.5	25
	7	Massive grayish-blue and dark-blue dolomite, almost free of chert	9.5	20.5
	6	Massive dolomite, upper portion light bluish-gray, free from chert; lower portion dark-bluish-gray; some chert	11	11
	5	Concealed		
		Section 400 feet west of above in same quarry.		
295	4	Dark-blue, somewhat cherty dolomite, heavy-bedded at the top and thin-bedded at the bottom	7.5	24.4
	3	Thin-bedded, fine-grained dark-blue dolomite	10.3	16.9
	2	Dark-blue massive dolomite with secondary calcite	3.6	6.6
	1	Gray dolomite	3	3

Several other exposures are found in the western portion of the quarry, but these were not sampled as they were not continuous over any considerable thickness.

The following analyses show the chemical composition of the units described above:

Analyses of Dolomite, One-Half Mile East of Graysville

Sample No.	294	295
Unit No.	6–10	1–4
Lime (CaO)	30.26	28.56
Magnesia (MgO)	18.64	20.98
Ferric oxide (Fe_2O_3)	.94	1.08
Sulphur trioxide (SO_3)	.00	.00
Phosphorus pentoxide (P_2O_5)	tr.	.01
Silica (SiO_2)	3.25	1.85
Clay bases	1.68	.51
Loss on ignition	45.23	47.01
	100.00	100.00

Hale property (Map location 4 Ca).—The Hale quarries are situated directly on the Western and Atlantic Railroad about 1½ miles southeast of Graysville. W. F. Hale, the owner of the property, first began the manufacture of lime at this point in the year 1901.

The stone quarried at this point is the upper Knox dolomite. It is a gray, heavy-bedded and massive, fine-grained, somewhat crystalline rock with chert scattered throughout many of the beds. The strike is N. 8° E., and the dip 17° SE.

The rock is drilled and blasted from the quarry face to quarry level. It is loaded by hand to tram conveyor which is drawn by pulley to the top of the kilns. Two vertical steel continuous feed kilns have a total daily capacity of about 225 barrels. The lime is sold in barrels and bulk. It is used chiefly for mortars in construction work, but has also been used to a limited extent for agricultural purposes.

The cherty limestone and chert are separated in the quarry from the dolomite, conveyed to a jaw-crusher where they are crushed and sold for ballast, etc. The unit designated No. 9 in the section contains chert associated with pyrite, calcite, galena, fluorite, barite, and a sample of this unit was found to contain some gold and silver, as shown by the following assay by Dr. Edgar Everhart:

Assay of Ore from the Hale Quarries

	Ounces per ton
Gold	3/100
Silver	1/5
Lead	0.54 %

The following section from top to bottom shows the physical character of the stone:

Section, Hale Quarries, 1 1/2 Miles Southeast of Graysville

Sample No.	Unit No.	Description of Units	Thickness feet	Total Thickness feet
296	23	Heavy-bedded and massive gray dolomite, containing in the upper portion several thin layers of chert	18.5	202.1
	22	Heavy-bedded gray dolomite, somewhat arenaceous, containing numerous thin beds of chert	10	183.6
297	21	Heavy-bedded and massive dolomite	8	173.6
298	20	Massive dolomite containing several layers of chert at the top. The lower 6 feet contains calcite of circular form interspersed throughout	7	165.6
	19	Massive gray nodular dolomite with rounded nodules of chert	4.5	158.6
299	18	Bluish-gray heavy-bedded dolomite	5	154.1
	17	Cherty dolomite	2	149.1
	16	Dark-blue massive dolomite	9	147.1
	15	Bluish-gray massive dolomite, speckled throughout with secondary calcite and some few chert nodules	3.8	138.1
	14	Dark grayish-blue heavy-bedded and massive dolomite; some chert in the upper part	11	134.3
	13	Massive gray cherty dolomite; chert parallel to the bedding more abundant near the top and bottom	13.5	123.3
	12	Massive and heavy-bedded dolomite, dark-blue at the top, grayish-blue towards thde middle with considerable chert; lower portion grayish-blue and dark blue	9	109.8
300	11	Gray heavy-bedded and massive dolomite	10	100.8
301	10	Grayish-blue, heavy-bedded and massive dolomite; slightly impure near top	5	90.8
		Bottom of quarry; section is continued along the W. and A. Railroad.		
	9	White and bluish-flint with dolomite, galena, flourite, and barite	5	85.8

Section, Hale Quarries, 1 1/2 Miles Southeast of Graysville—Continued

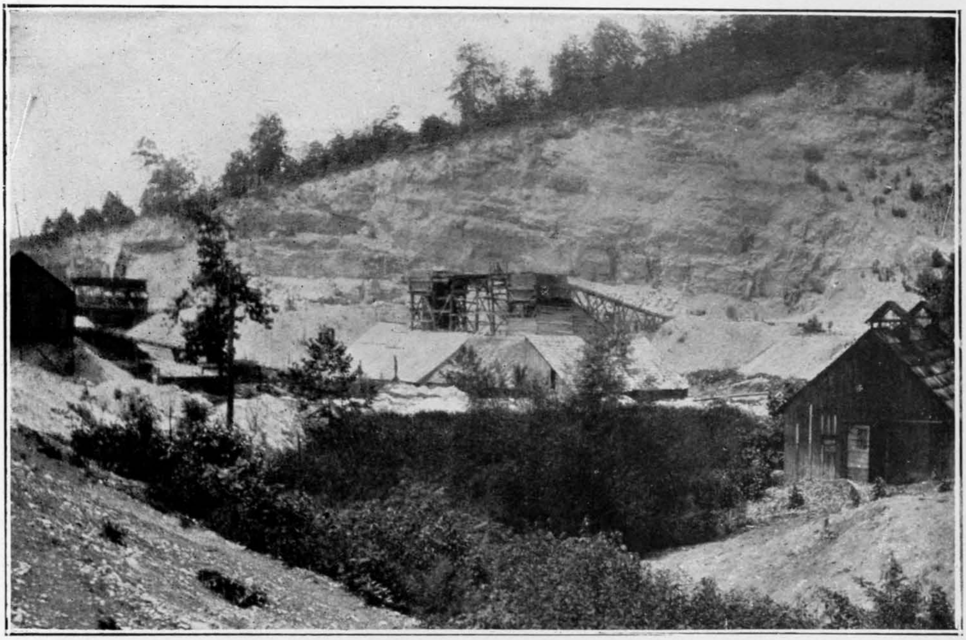
Sample No.	Units No.	Description of Units	Thickness feet	Total Thickness feet
	8	Gray dolomite	4.7	80.8
	7	Chert containing galena	1.5	76.1
	6	Fine-grained massive gray dolomite	5.5	74.6
	5	Interbedded dolomite with chert		
	4	Massive gray heavy-bedded dolomite with considerable chert throughout	11.3	69.1
	3	Massive gray fine-grained dolomite with considerable chert	18.8	57.8
	2	White and blue chert	4	39
	1	Heavy-bedded gray dolomite with some thin beds. A large amount of chert in thin layers parallel to the bedding with some nodular chert	35	35

The following analyses show the composition of the individual beds described in the above section:

Analyses of Dolomite from Hale Quarries

Sample No.	296	297	298	299	300	301
Unit No.	22–23	21	20	12–18	11	10
Lime (CaO)	28.62	31.50	31.20	33.12	27.28	30.16
Magnesia (MgO)	16.60	18.30	17.80	16.60	17.60	18.70
Ferric oxide (Fe_2O_3)	1.28	.90	1.32	.92	.90	.68
Sulphur trioxide (SO_3)	.03	.01	.01	tr.	.02	.02
Phos. pentoxide (P_2O_5)	.02	.02	.02	.02	.02	.02
Silica (SiO_2)	8.54	3.60	3.40	3.43	11.76	4.64
Clay bases	4.10	1.37	1.70	1.46	.82	1.23
Loss on ignition	40.81	44.30	44.97	44.05	41.58	44.55
	100.00	100.00	100.00	100.00	100.00	100.00

Cedar Bluff (Map location 5 Ca).—Cedar Bluff is located on Catoosa Ridge at a point about three-fourths mile south of the Georgia-Tennessee line. The Bangor limestone is largely exposed from the bottom of the ridge to within 25 feet of the top, this upper 25 feet being Lookout sandstone. The limestone is heavy-bedded, light-blue in color, and varies somewhat in lithologic character. Some beds are semi-crystalline, others almost holo-crystalline, or fossiliferous.



A. QUARRY OF KNOX DOLOMITE, KILNS AND STONE HOUSE, HALE PROPERTY, ABOUT 1½ MILES SOUTHEAST OF GRAYSVILLE, CATOOSA COUNTY, GEORGIA

B. KNOX DOLOMITE, LADD LIME COMPANY'S QUARRY, SHOWING HEAVY-BEDDED AND MASSIVE DOLOMITE, BARTOW COUNTY, GEORGIA

Section from Top to Bottom, Cedar Bluff

Sample No.	Units No.	Description of Units	Thickn ss feet	Total Thickness feet
	8	Sandstone	25	277.
302	7	Semi-crystalline gray to grayish-blue heavy-bedded and massive limestone containing *archimedes* sp. at the bottom	69.6	252.0
	6	Concealed	23.2	182.4
303	5	Somewhat fine semi-crystalline heavy-bedded limestone; partly concealed	45	159.2
	4	Cherty nodular limestone	8	114.2
304	3	Gray to bluish-gray, heavy-bedded, semi-crystalline limestone; some beds fine grained near top	19.2	106.2
305	2	Gray to grayish-blue, heavy-bedded semi-crystalline limestone	46.4	87
306	1	Heavy-bedded limestone somewhat variable in lithologic character; semi-crystalline at and near the bottom, above which occur fine-grained limestone succeeded by fossiliferous limestone, largely crinoidal and semi-crystalline	40.6	40.6

The following analyses show the composition of the units described in the above section:

Analyses of Limestone from Cedar Bluff

Sample No.	302	303	304	305	306
Unit No.	7	5	3	2	1
Lime (CaO)	51.10	53.30	53.00	54.44	53.95
Magnesia (MgO)	1.95	1.00	1.00	.10	.20
Ferric oxide (Fe_2O_3)	.48	.20	.66	.72	.62
Sulphur trioxide (SO_3)	.00	.02	tr.	.00	.02
Phosphorus pentoxide (P_2O_5)	.00	.03	.02	tr.	.03
Silica (SiO_2)	1.76	1.80	2.80	1.26	2.24
Clay bases	2.55	.70	.64	.62	.98
Loss on ignition	42.16	42.95	41.88	42.86	41.96
	100.00	100.00	100.00	100.00	100.00

WHITFIELD COUNTY

GEOLOGY

Connasauga Shales and Limestones

The Connasauga formation is made up largely of yellowish-green argillaceous shales with some limestones, which reach a thickness of about 200 feet along Cedar Ridge. The ratio of silica to alumina in the shales is too low to make them attractive for use in the manufacture of Portland cement.

The limestones are characterized by argillaceous intercalations and fine grain. Some of the beds contain such a high percentage of carbonaceous matter that they are black in color. The content of magnesia seldom exceeds 4 per cent. They are in places chemically suitable for use in the manufacture of Portland cement. The conditions, however, which affect their commercial use for this purpose, such as nearness of a suitable shale, transportation, etc., are not favorable. This limestone will prove to be the most important commercial stone in the county for the burning of lime, road metal, ballast, etc.

Chickamauga Formation

The formation to the west of Chattoogata Mountain is made up essentially of vari-colored argillaceous shales with some few interbedded argillaceous limestones. The limestones are almost entirely absent to the east of this mountain, and are never of sufficient thickness to become of value for economic use. The shales are too variable in their physical character for use in the manufacture of cement.

Rockwood Formation

The shales of this formation are usually interbedded with the sandstones. They occur in great abundance to the west of Chattoogata Mountain, while the sandstones predominate to the east. Yellow sandy shales are found in the lower portion of the formation, with very few shales in the middle, while yellowish argillaceous shales are occasionally interbedded with sandstones in the upper portion. The silica-alumina ratio is either too high or too low and the sandstones are in such great abundance that the shales are seldom commercially available for use in the manufacture of cement.

DESCRIPTION OF INDIVIDUAL LOCALITIES

Ducketts Mill (Map location 1 Wh).—The Connasauga limestone is exposed east of Ducketts Mill on the property of I. S. Duckett, along the south side of the Dalton-Spring Place road. The limestones are grayish-blue and dark-blue in color and thin-bedded. They are exposed over a horizontal distance of 360 feet. The strike is N. 11° E., and the dip, 25° SE.

The following section begins at the uppermost exposure of the limestone:

Section at Ducketts Mill

Sample No.	Unit No.	Description of Units	Thickness feet	Total Thickness feet
307	4	Thin shaly and heavy-bedded, dark-blue and black limestone. Shaly limestome omitted in sample	12	61.5
	3	Concealed	10.2	49.5
307	2	Thin and heavy-bedded dark-blue limestone with some chert	22.2	39.3
	1	Dark-blue and grayish-blue thin-bedded shaly limestone, approaching a calcareous shale in places	17.1	17.1

The following analysis shows the composition of units 2 and 4 in the above section:

Analysis of Limestone from Ducketts Mill
(Sample No. 307)

Lime (CaO)	38.78
Magnesia (MgO)	9.40
Ferric oxide (Fe_2O_3)	1.46
Sulphur trioxide (SO_3)	.02
Phosphorus pentoxide (P_2O_5)	.03
Silica (SiO_2)	6.02
Clay bases	2.78
Loss on ignition	41.51
	100.00

One mile north of Ducketts Mill (Map location 2 Wh).—One mile north of Ducketts mill on the west side of Cedar Ridge, the dark-blue and black limestones of the Connasauga formation are exposed over a vertical thickness of 110 feet. Two openings were made at this point on the hillside some years ago in the search for a black marble. The limestone has been burned and used for agricultural purposes.

Section from Top to Bottom, one Mile North of Ducketts Mill

Sample No.	Unit No.	Description of Units	Thickness feet	Total Thickness feet
308	2	Thin-bedded, bluish-gray and dark-blue limestone, largely concealed; chert scattered over the surface	75.4	110.2
	1	Heavy-bedded, dark-bluish-gray and black limestone	34.8	34.8

The following analysis shows the composition of unit 2 in the above section:

Analysis of Limestone One Mile North of Ducketts Mill

(Sample No. 308)

Lime (CaO)	44.06
Magnesia (MgO)	5.40
Ferric oxide (Fe_2O_3)	.70
Sulphur trioxide (SO_3)	.01
Phosphorus pentoxide (P_2O_5)	tr.
Silica (SiO_2)	6.40
Clay bases	2.89
Loss on ignition	40.54
	100.00

Jet Black Marble Company (Map location 3 Wh).—The property of the Jet Black Marble Company is located on the west side of Cedar Ridge 1½ miles north of Ducketts Mill. The limestone exposed at this point occurs in the Connasauga formation. Several quarries were at one time prospected with the hope of locating commercial marble. The limestones are somewhat massive in appearance and contain thin argillaceous intercallations. The strike is N. 2° E., and the dip 15° SE.

Section from Top to Bottom, Jet Black Marble Company

Sample No.	Unit No.	Description of Units	Thickness feet	Total Thickness fe t
309	1	Some exposures of bluish-gray, fine-grained limestone with chert	95.2	223.9
	3	Heavy-bedded and massive, bluish-gray limestone, in places somewhat argillaceous	69.8	128.7
310	2	Massive bluish-gray, fine-grained limestone	44.8	59.8
	1	Bluish-gray shale	15	15

The following analyses show the composition of the limestone in the above section:

Analyses of Limestone, Jet Black Marble Company

Samplw No.	309	310
Unit No.	4	2–3
Lime (CaO)	44.32	42.52
Magnesia (MgO)	4.40	4.70
Ferric oxide (Fe_2O_3)	1.14	1.70
Sulphur trioxide (SO_3)	.00	.06
Phosphorus pentoxide (P_2O_5)	tr.	tr.
Silica (SiO_2)	6.52	6.17
Clay bases	3.88	6.35
Loss on ignition	39.74	38.50
	100.00	100.00

Cedar Ridge, north of the Dalton-Dawnville road (Map location 4 Wh).—The limestones of the Connasauga formation are exposed at a point about one mile north of the Dalton-Dawnville road, on the west side of Cedar Ridge. The limestone appears somewhat massive, but is thin-bedded and fine grained. Certain strata are fossiliferous, containing fragments of *trilobites* and a specie of *Girvanella* in abundance. The section from top to bottom is as follows:

Section, Cedar Ridge, North of Dalton-Dawnville Road.

Sample No.	Unit No.	Description of Units	Thickness feet	Total Thickness feet
311	3	Bluish-black, thin-bedded, fine-grained limestone. A fossiliferous zone was observed 20 feet below the top	46.4	158.8
312	2	Grayish-blue, fine grained limestone thin-bedded at top and bottom, and heavy-bedded near the middle	54.4	112.4
313	1	Heavy-bedded, dark-grayish-blue and dark-blue, fine grained limestone Trilobites and *Girvanella* sp. found 20 feet from bottom	58	58
		Yellowish-green fissile argillaceous shale	0	0

The following analyses show the composition of the individual units described in the above section:

Analyses of Limestone from Cedar Ridge

Sample No.	311	312	313
Unit No.	3	2	1
Lime (CaO)	39.64	50.14	46.90
Magnesia (MgO)	4.40	2.20	3.10
Ferric oxide (Fe_2O_3)	1.34	1.06	1.46
Sulphur trioxide (SO_3)	--------	.00	.01
Phosphorus pentoxide (P_2O_5)	--------	tr	.02
Silica (SiO_2)	7.28	3.62	6.22
Clay bases	3.64	1.36	2.03
Loss on ignition	43.70	41.62	40.26
	100.00	100.00	100.00

Four miles northeast of Dalton (Map location 5 Wh).—The argillaceous yellow and green shales of the Connasauga formation are exposed at a point about four miles northeast of Dalton along the road which parallels Cedar Ridge and about 1½ miles east of the ridge. The silica-alumina ratio is low, so they cannot be used alone in the manufacture of cement. The strike is N. 3° E., and the dip 80° SE.

The following analysis shows the composition of an average sample taken over the entire exposure of 1,000 feet along the roadside:

Analyses of Shales, 4 Miles Northeast of Dalton
(Sample No. 314)

Moisture at 100° C.	.67
Loss on ignition	9.82
Lime (CaO)	.10
Magnesia (MgO)	1.74
Alumina (Al_2O_3)	20.79
Ferric oxide (Fe_2O_3)	7.39
Titanium dioxide (TiO_2)	.92
Silica (SiO_2)	56.20
	97.63

Two miles due north of Dalton (Map location 6 Wh).—Limestones of the Connasauga formation are exposed on the property of D. Puryear at a point 2 miles due north of Dalton, and only a few hundred feet east of the public road. The exposure extends over a thickness of 10 stratigraphic feet and parallels the strike for about 100 feet.

The limestone will make a good road material and can be used also for the burning of an agricultural lime. The conditions which affect development prevent its use in the manufacture of Portland cement. The strike is due east and west, and the dip is to the north at a low angle.

The following analysis shows the composition of an average sample taken over the entire exposure:

Analysis of Limestone from D. Puryear Property
(Sample No. 315)

Lime (CaO)	50.14
Magnesia (MgO)	2.20
Ferric oxide (Fe_2O_3)	1.06
Sulphur trioxide (SO_3)	.00
Phosphorus pentoxide (P_2O_5)	tr.
Silica (SiO_2)	3.62
Clay bases	1.36
Loss on ignition	41.62
	100.00

Three and one-half miles east of Waring (Map location 7 Wh).—Three and one-half miles east of Waring and about three-fourths mile east of Coahulla Creek, the yellowish-green argillaceous shales of the Connasauga formation are exposed just west of the public road for a thickness of about 1,000 feet. The percentage of alumina is too high and the silica too low for their use in the manufacture of cement.

The following analysis shows the composition of the shales at this point:

Analysis of Shales 3 1/2 Miles East of Waring

(Sample No. 316)

Moisture at 100° C.	.90
Loss on ignition	7.02
Lime (CaO)	.00
Magnesia (MgO)	1.44
Alumina (Al_2O_3)	21.21
Ferric oxide (Fe_2O_3)	7.39
Titanium dioxide (TiO_2)	1.28
Silica (SiO_2)	60.26
	99.50

Dantzler property (Map location 8 Wh).—The Connasauga limestone outcrops on the property of Mr. Dantzler, about one-half mile east of Praters Mill. The limestone occupies the hill from the base to the top, but the exposure is not continuous. The rather high content of magnesia and absence of available shales will prevent its use in the manufacture of Portland cement. The stone is suitable for road metal, ballast, concrete, and for the manufacture of lime.

The following analysis shows the average composition of the limestone at this point:

Analysis of Limestone from Dantzler Property

(Sample No. 317)

Lime (CaO)	45.28
Magnesia (MgO)	4.20
Ferric oxide (Fe_2O_3)	1.20
Sulphur trioxide (SO_3)	.02
Phosphorus pentoxide (P_2O_5)	tr.
Silica (SiO_2)	6.40
Clay bases	2.45
Loss on ignition	40.45
	100.00

MURRAY COUNTY

GEOLOGY

Connasauga Shales and Limestones

The Connasauga formation consists essentially of argillaceous shales and interbedded limestones. The limestones sometimes attain a thickness of more than 100 feet, but usually they are only a few feet in thickness. They are fine grained, thin-bedded, grayish-blue in color, and contain many argillaceous impurities. The percentage of magnesia is usually below 5 per cent.; however, the conditions which affect their development, such as association of shales of suitable composition, fuel supply, transportation facilities, quarry openings, etc., will in all probability prevent their use in the manufacture of Portland cement in this county.

The ratio of silica to alumina in the Connasauga shales is too low to make them of any value for use in the manufacture of cement.

Knox Dolomite

The Knox dolomite occupies a large valley area extending in a general north and south direction from the Georgia-Tennessee line to a point several miles south of Spring Place. The dolomite is in many places concealed by a thick residual soil. On account of its usual occurrence below water level it is not an easy matter to procure it for the manufacture of lime. The high percentage of magnesia is objectionable for its use in the manufacture of Portland cement.

Chickamauga Formation

The Chickamauga formation in this county is made up of varicolored argillaceous shales and sandstones, while limestones are almost entirely absent. The variable character of the shales renders them unattractive for use in the manufacture of Portland cement.

The limestones and shales occur only in the western portion of Murray County in the Great Appalachian Valley area. The shales do not fulfill the requirements for the manufacture of Portland cement, while the limestones are so seldom exposed over a thickness sufficient for economic development that it was not thought advisable to sample any individual localities.

GORDON COUNTY

GEOLOGY

Connasauga Shales and Limestones

The Connasauga formation in Gordon County is essentially the same as in Murray County described above. The most important calcareous and argillaceous materials found in this county, and those which will prove to be of the greatest commercial importance, are found in the Connasauga formation. They are of value for use as road metal, ballast, and for the local manufacture of lime for agricultural purposes. They carry a content of magnesia well within the limits prescribed for use in the manufacture of Portland cement, yet the conditions which affect their development, such as available shales, fuel supply, etc., will prevent their use for this purpose in the immediate future. The ratio of the silica to the alumina in the shales is too low to make them of value for use in the manufacture of cement.

Knox Dolomite

The high percentage of magnesia contained in the Knox dolomite is objectionable for its use in the manufacture of Portland cement. This rock can be best used for road material.

DESCRIPTION OF INDIVIDUAL LOCALITIES

One mile southeast of Fairmount (Map location 1 G).—One mile southeast of Fairmount on the north side of the Tennessee road and immediately north of the bridge over Sallocoa Creek, the limestones and shales of the Connasauga formation are exposed. The limestones at this point have a thickness of more than 100 feet. They are dark grayish-blue, fine-grained and often semi-crystalline and contain many argillaceous intercalations with some secondary calcite in veins. The strike is N. 10° W., and the dip 20° NE.

The following analysis shows the composition of an average sample taken over the entire exposure at this point:

Analysis of Limestone One Mile Southeast of Fairmount

(Sample No. 318)

Lime (CaO)	49.20
Magnesia (MgO)	1.46

Ferric oxide (Fe_2O_3)	.40
Sulphur trioxide (SO_3)	.00
Phosphorus pentoxide (P_2O_5)	tr.
Silica (SiO_2)	2.76
Clay bases	3.14
Loss on ignition	43.04
	100.00

One mile southwest of Fairmount (Map location 2 G).—One mile southwest of Fairmount and on the north side of the Fairmount-Adairsville public road, limestones of the Connasauga formation are exposed over about 30 stratigraphic feet. These limestones are interbedded with some few argillaceous shales. They are thin-bedded with a somewhat massive appearance, dark-blue in color, fine-grained with some laminae of clayey impurities.

One mile northeast of Pine Log Creek (Map location 3 G).—Limestones and shales of the Connasauga formation outcrop about one mile northeast of Pine Log Creek, on the Fairmount-Adairsville public road. The limestones are poorly exposed so that it is difficult to get an average sample over their entire thickness. They resemble in lithologic character the limestones which occur elsewhere in this formation in this vicinity.

BARTOW COUNTY

GEOLOGY

Beaver Limestone

The Beaver limestone in Bartow County is largely concealed and is usually valley-forming. In the few exposures which occur the limestone is grayish-blue, semi-crystalline and massive. It can be best used in the local construction of roads. On account of the conditions which affect its development it will seldom be commercially available for lime while the high percentage of magnesia makes it objectionable for use in the manufacture of Portland cement.

Rome Formation

The Rome formation is made up essentially of vari-colored argillaceous shades with some sandstones. The variable character of the shales and their low silica-alumina ratio make them unattractive for use in the manufacture of Portland cement.

CONNASAUGA SHALES AND LIMESTONES

The Connasauga formation consists essentially of argillaceous shales with some interbedded limestones. The limestones can be used for road metal, ballast, concrete, and lime. The content of Magnesia is usually below 4 per cent., and in some places there is no serious objection chemically against its use in the manufacture of Portland cement. However, the fact that not only the shales of this formation, but also those in adjacent formations, have a silica-alumina ratio considerably below 3 to 1 make the conditions unfavorable for the successful operation of a cement plant.

KNOX DOLOMITE

The Knox dolomite in Bartow County is usually exposed only in the upper portion of the formation. This portion of the formation contains much chert which is found both as layers and as nodules. The crushed dolomite can be used for road metal, ballast, concrete, fluxing, etc. The burned stone makes a highgrade lime. The high percentage of magnesia prohibits its use in the manufacture of Portland cement, but at the same time there are certain beds which will make an excellent natural cement.

CHICKAMAUGA LIMESTONES AND ROCKMART SHALES

In the extreme southwest portion of the country there are some exposures of the Chicamauga limestone and the Rockmart shales. The limestone is valley forming and the conditions which affect its development prevent its use in this county in the manufacture of Portland cement. The Rockmart shales are eminently suitable in every way as a mix in the manufacture of Portland cement.

DESCRIPTION OF INDIVIDUAL LOCALITIES

Two miles south of Sophia (Map location 1 B).—The Beaver limestone is exposed at a point about two miles south of Sophia, on the east side of the road between Sophia and Grassdale. The limestone outcrops over a stratigraphic thickness of about 30 feet and is overlain by shales of the Rome formation.

The limestone is heavy-bedded and massive, semi-crystalline, and of a gray-blue to dark-blue color. The shales which overlie the limestone are considerably metamorphosed and contain much secondary amorphous quartz in the form of stringers. The shales are characteristically fissile and of variegated color. The rocks strike N. 78° E., and dip 20° NW.

The following analyses show the chemical composition of this limestone and shale:

Analyses of Limestone and Shale, 2 Miles South of Sophia

Sample No.	Limestone 319	Shale 320
Moisture at 100° C	----------	.80
Loss on ignition	----------	7.70
Lime (CaO)	30.30	.44
Magnesia (MgO)	19.56	2.90
Alumina (Al_2O_3)	----------	29.44
Ferric oxide (Fe_2O_3)	1.26	6.80
Sulphur trioxide (SO_3)	.00	--------
Phosphorus pentoxide (P_2O_5)	.02	--------
Silica (SiO_2)	1.76	48.64
Soda (Na_2O)	.08	1.22
Potash (K_2O)	.10	1.48
Manganese (MnO)	----------	tr.
Titanium dioxide (TiO_2)	----------	.82
Clay bases	.78	--------
Loss on ignition	46.14	--------
	100.00	100.00

Folsom (Map location 2 B).—At a point several hundred feet west of Cedar Creek and just north of the Adairsville-Fairmount public road a dark-blue, heavy-bedded somewhat fine-grained limestone of the Connasauga formation is exposed over a stratigraphic thickness of from 50 to 75 feet. The limestone occupies a small hill and extends from the base to the top of the hill, a vertical height of about 40 feet. The stone is badly weathered, contains much secondary calcite and is very similar in lithologic character and chemical composition to other limestones found in the same formation throughout this area. The strike is N. 20° E., and the dip 30° NW.

Four miles east of Folsom (Map location 3B).—Four miles east of Folsom, just east of the road which parallels Rocky Branch, the limestones of the Connasauga formation are exposed on the property of Mr. Nally. The limestone is dark-blue, fine-grained, and appears to be somewhat heavy-bedded. It occupies three low hills and outcrops across the strike for about 150 feet.

The following analyses show the composition of samples taken across the strike from the several points designated on the map:

Analyses of Limestone, 4 Miles East of Folsom

Sample No.	321	322
Lime (CaO)	51.80	52.74
Magnesia (MgO)	2.00	1.65
Ferric oxide (Fe_2O_3)	.12	.96
Sulphur trioxide (SO_3)	.00	.00
Phosphorus pentoxide (P_2O_5)	.02	.01
Silica (SiO_2)	1.50	1.10
Clay bases	1.16	.32
Loss on ignition	43.40	43.22
	100.00	100.00

Georgia Green Slate Company (Map location 4 B).—The quarry of the Georgia Green Slate Company is located on the Louisville and Nashville Railroad about 1¼ miles northeast of Boliver station. The slates belong to the Connasauga formation which at this point is made up of green slates and grayish-blue limestone. The quarry recently opened has been worked along the strike to a depth of about 35 feet. The strike is N. 50° E., and the dip 13° SE.

The following analysis shows the character of an average sample which was taken over the entire quarry exposure:

Analysis of Georgia Green Slate

(Sample No. 323)

Moisture at 100° C.	.28
Loss on ignition	5.11
Lime (CaO)	.73
Magnesia (MgO)	2.50
Alumina (Al_2O_3)	22.60
Ferric oxide (Fe_2O_3)	1.68

Ferrous oxide (FeO)	5.74
Sulphur trioxide (SO_3)	.37
Phosphorus pentoxide (P_2O_5)	tr.
Silica (SiO_2)	55.30
Soda (Na_2O)	1.40
Potash (K_2O)	2.90
Manganese (MnO)	.08
Titanium dioxide (TiO_2)	.73
Carbon dioxide (CO_2)	.83
	100.25

Ladd Lime Company (Map location 5 B).—The property of the Ladd Lime Company is located on the Seaboard Railroad about two miles southwest of Cartersville.

The quarry opening is along the southeast end of Ladd Mountain, in the upper portion of the Knox dolomite. Along the eastern edge of this mountain there is a fault zone of conglomerate which has a width of about 15 feet. This fracture zone is made up of bluish-gray and light gray angular fragments of dolomite cemented together by calcareous and siliceous matrix. The rocks have been much shattered and broken for a distance in places of 50 feet on the west side of the fault. Frequently large quantities of silica and clay impurities are contained in this rock mass. After the fracturing of these rocks took place underground waters carrying lime in solution deposited it in these open fissures, so that they are partially filled with calcite which, however, is never in sufficient quantity to be of any commercial importance. West of the fractured zone the strike is N. 50° E., and the dip 32° SE.

Three systems of joints aid greatly in quarrying the stone. However, their abundance will probably prohibit the use of the stone for building purposes. One system of joints filled with clay has a general east and west direction; the second system has a general northeast and southwest direction; while the third system intersects these two systems of joints.

The following section was made in what is known as quarry No. 1, which will give a general idea of the physical character of the stone:

Section, Ladd Lime Company's Quarry

Sample No.	Unit No.	Description of Units	Thickness feet	Total Thickness feet
	10	Cherty dolomite	150–200	296.7
	9	Sandy dolomite (not sampled)	3	96.7
324	8	Grayish-blue dolomite containing a three-inch layer of chert at a point 3 feet above the bottom	10	93.7
325	7	Gray dolomite	22	83.7
326	6	Grayish-blue dolomite	15.5	61.7
	5	Dark-blue dolomite	5.5	46.2
	4	Sandy dolomite with iron and clay impurities. This unit contains too many impurities for lime burning or fluxing stone; not sampled	10	40.7
	3	Sandy, somewhat unconsolidated dolomite	3	30.7
327	2	Grayish-blue dolomite	5.8	27.7
328	1	Gray dolomite; quarry floor	21.9	21.9

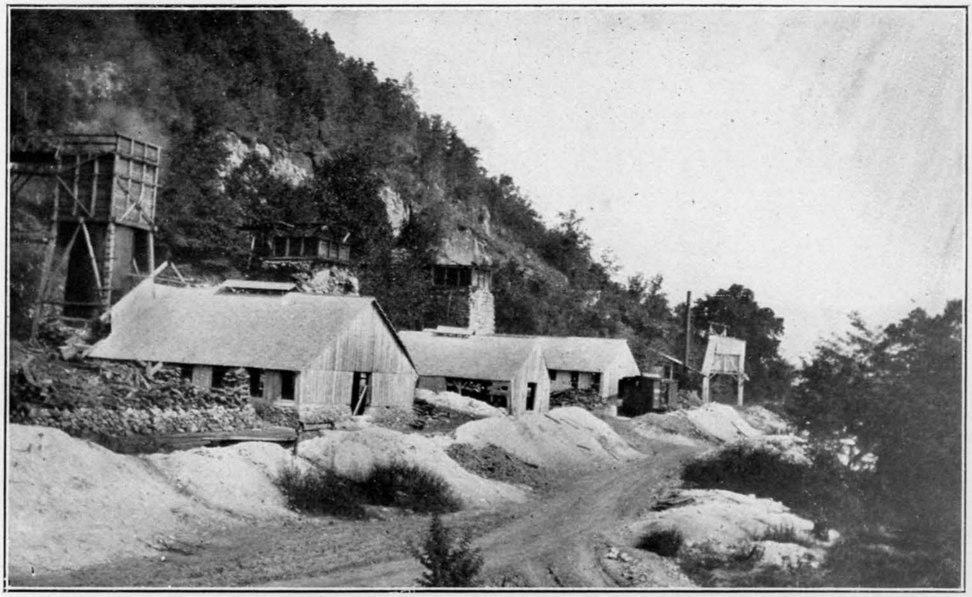
The following chemical analyses shows the composition of the units described above:

Analyses of Dolomite, Ladd Lime Company

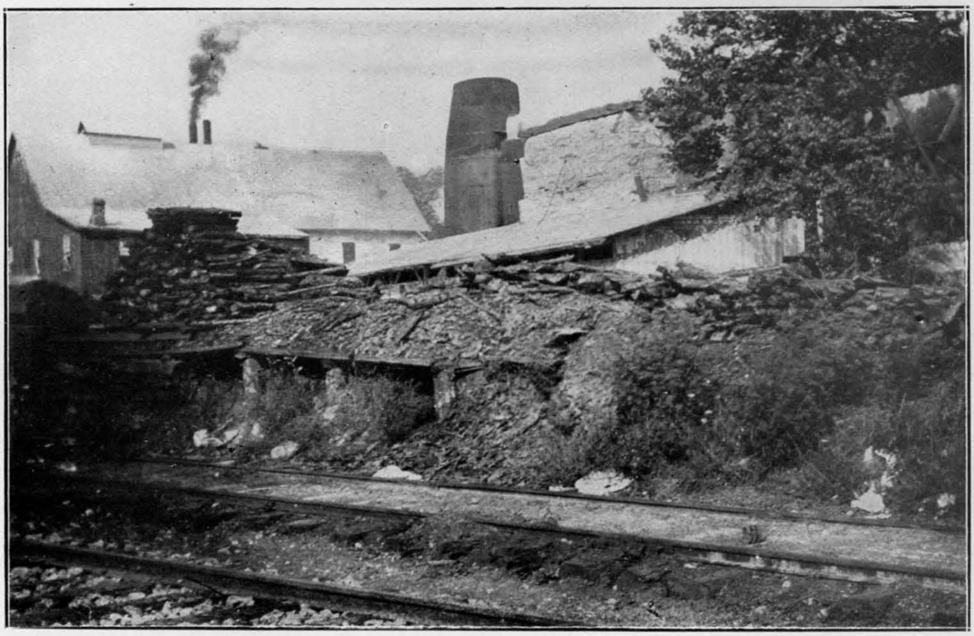
Sample No.	324	325	326	327	328
Unit No.	8	7	5–6	2	1
Lime (CaO)	31.37	33.62	24.70	34.33	31.59
Magnesia (MgO)	14.74	14.89	13.90	18.85	20.72
Ferric oxide (Fe_2O_3)	1.09	1.19	1.08	.85	.72
Silica (SiO_2)	22.03	5.00	2.96	.57	.16
Clay bases	.33	.76	1.13	1.33	1.33
Loss on ignition	30.44	44.54	56.23	44.07	45.37
	100.00	100.00	100.00	100.00	100.00
Specific gravity	2.73	2.84	3.13	2.85	2.87

CONDITIONS AFFECTING DEVELOPMENT

The dolomite is exposed from the top to the bottom of the quarry over a stratigraphic thickness of 91 feet, while the cherty dolomite



A. LADD LIME COMPANY, LOCATED ABOUT 2 MILES SOUTHWEST OF CARTERSVILLE, BARTOW COUNTY, SHOWING LADDS MOUNTAIN, LIME KILNS, AND CRUSHED STONE BINS



B. LIME KILNS AND CEMENT MILL, HOWARD HYDRAULIC CEMENT COMPANY, CEMENT, GEORGIA extends from the top of the quarry to the top of the mountain. The horizontal extent of the exposure along the east side of the mountain is about 1,000 feet. The quarries are located about 40 feet above the general level of the valley, so that drainage is natural and the quarries should always be dry. The kilns are so situated that the stone can be conveyed from the quarry to the kilns by means of a gravity tram. The rock best suited for lime consists of units 1, 2, 5, 6, and 7. Units 1 and 2 are best suited for paper manufacture, fluxing stone, lining of furnaces, and glass manufacture, while units 5, 6, 7, and 8 can also be used for like purposes. As long as the cherty dolomite is quarried previous to that of the underlying dolomite and used for ballast, concrete, etc., it can not be considered as overburden.

DEVELOPMENT

The quarry is an open cut. The rock is drilled and blasted from place and then broken into convenient size for handling. It is loaded on cars of a gravity tram and taken either to the crusher or to the kilns. The kilns are four in number, about 40 feet in height with separate feed. Wood is used as a fuel. The lime is packed in barrels or shipped in bulk.

USES

The individual beds of the quarry differ both in their physical and chemical character and different beds are best adapted for certain uses. This dolomite can be used for the lining of furnaces, for blast furnace flux, in the manufacture of flint and plate glass, concrete, ballast, road metal, for the sulphite process in the manufacture of paper, and for mortars and plasters. The value of this lime for agricultural purposes depends both on the character of the soil and the nature of the crop to be grown.

Howard Hydraulic Cement Company (Map location 6 B).—The property of the Howard Hydraulic Cement Company is located on the Western and Atlantic Railroad at Cement station. Natural cement rock as previously stated was found at this point in the year 1850 by the Rev. Charles H. Howard, of Charleston, S. C. A company was organized in 1851, and the manufacture of a natural cement was begun during that year.

GEOLOGICAL RELATIONS

The natural cement rock is found in the Knox dolomite formation. Otto Veatch, former assistant State geologist, furnished the following section:

Section, Howard Hydraulic Cement Company

Sample No.	Unit No.	Description of Units	Thickness feet	Total Thickness feet
329	3	Dolomite and residual clay and flint. Upper "Cement strata"; 20 inches of rock occuring near the middle of of this strata; contains too high percentage of lime for use	5.9	23.9
	2	Bastard rock	11	18
330	1	Black fine-grained compact dolomite intimately veined with coarsely crystalline calcite; lower layer can be used alone or can be mixed about half and half with the upper layer, in places too calcitic to be used	7	7
		Some thin seams of black flint, about one-half inch thick occur but not abundant		

The following analyses show the composition of the units described above:

Analyses of Dolomite, Howard Hydraulic Cement Company

Sample	329	330
Unit No.	3	1
Lime (CaO)	32.10	29.50
Magnesia (MgO)	4.10	16.30
Alumina (Al_2O_3)	2.48	3.59
Ferric oxide (Fe_2O_3)		1.55
Silica (SiO_2)	28.42	7.15
Loss on ignition	32.90	41.91
	100.00	100.00

CONDITIONS AFFECTING DEVELOPMENT

The natural cement beds are separated from one another by dolomite which is not suitable for the manufacture of a natural cement. On this account the natural "cement rock" can be most economically won by mining. The dip of the beds is only 8°, so that the slope of the drifts is gentle.

DEVELOPMENT

The stone is blasted from place in the mine and broken, so that it can be handled by the miner. It is then loaded by hand on small cars and conveyed to the kilns along an incline. The kilns are of the dome type and six in number. Four upright kilns are jacketed with steel and lined with fire brick, clay occupying the span between the jacket and the lining. These four kilns have a daily capacity of 75 barrels each. Two kilns have their exteriors built of rock. These rock-jacketed kilns have a daily capacity of 40 barrels each. The kilns are all 25 feet in length. They are charged with fuel and cement rock in alternate layers. It requires about three days for thorough calcination to take place. The calcined rock is drawn at the bottom of the kiln and conveyed to a frustrum and cone crusher, and the crushed clinker is conveyed by elevator buckets to a screen of 100 mesh. The material which does not pass through the screen is conveyed to buhrstones where it is ground. It is then sacked for shipment.

The following analyses show the composition of the Howard cement:

Analyses of Howard Hydraulic Cement

<table>
<tr><th>Cinstituents</th><th>I</th><th>II</th></tr>
<tr><td>Lime (CaO)</td><td>48.18</td><td>48.86</td></tr>
<tr><td>Magnesia (MgO)</td><td>15.00</td><td>18.14</td></tr>
<tr><td>Alumina (Al_2O_3)</td><td>3.35</td><td rowspan="2">11.60</td></tr>
<tr><td>Ferric oxide (Fe_2O_3)</td><td>7.23</td></tr>
<tr><td>Silica (SiO_2)</td><td>22.58</td><td>19.50</td></tr>
</table>

I Cummings, Uriah, American Cements, 1898, p. 35.

II W. M. Bowron, analyst, Eckel, E. C., Clements, Limes and Plasters, 1907, p. 253.

Clifford Lime and Stone Company (Map location 7 B).—The property of the Clifford Lime and Stone Company is located three miles northwest of Kingston, on a spur track of the Western and Atlantic Railroad.

GEOLOGIC RELATIONS

The entire exposure belongs to the Knox dolomite formation. The dolomite is largely crystalline, of a bluish-gray or light-gray color and breaks with an uneven fracture. The lower strata in the quarry contain layers and nodules of chert which should be separated from the dolomite and should never be allowed to enter the kiln.

The dolomite outcrops for about 450 feet in a horizontal direction N. 75° W., and not more than 50 feet in a vertical direction. This constitutes the quarry exposure. The quarry is situated above the general level of the valley so that the drainage is natural and with the proper quarry development a very considerable tonnage of dolomite is available above water level. The overburden consists of about 10 feet of residual red clay soil. The dip is 15° SW.

Section of Cement Strata, Clifford Lime and Stone Company

Sample No.	Unit No.	Description of Units	Thickness feet	Total Thickness feet
331	6	Dark-gray, fine-grained "cement rock"	2.3	7.3
	5	Chert	.1	5.4
	4	Dark-gray, fine-grained "cement rock"	.7	5.3
	3	Chert	.1	4.6
	2	Black cement rock	1.2	4.5
	1	Dark-gray, fine-grained "cement rock"	3.3	3.3

The analysis of sample 331 shows the general chemical character of the entire exposure. Chert was omitted in sampling. Sample 332 shows the chemical composition of the natural cement strata.

Analyses of Dolomite, Clifford Lime and Stone Company Development

Sample No.	331	332
Unit No.	1–6	
Lime (CaO)	31.16	25.00
Magnesia (MgO)	18.37	16.00
Alumina (Al_2O_3)	2.20	2.86
Ferric oxide (Fe_2O_3)		2.60
Sulphur trioxide (SO_3)	.00	.00
Phosphorus pentoxide (P_2O_5)	4.29	15.40
Silica (SiO_2)	43.98	38.13
	100.00	100.00

DEVELOPMENT

The rock is drilled and blasted from place, then broken into conenient size to be handled by the quarryman, loaded on cars and conveyed by rope pulley along an incline to the kilns or taken to the crusher.

There are two bottle-shaped kilns, steel or iron jacketed, with a daily capacity of about 125 barrels each. The kilns are about 30 feet in height and 12.3 feet in their greatest diameter. The dolomite and fuel are fed in alternate layers at the top and the burnt stone is drawn at the bottom of the kilns. The calcined dolomite is then loaded into wheelbarrows and dumped into a small Walker and Elliott crusher. The grindings from this crusher pass over screens, the fines going to the bins and the coarse material to the buhrstones. It is then sacked. The brand and trade name is "Etowah."

USES

This dolomite will make a good building lime, when calcined, and can also be used for the following purposes: blast furnace, manufacture of flint and plate glass, manufacture of paper, and crushed stone products.

The fact that the stone is a dolomite running high in magnesia prevents its use in the manufacture of Portland cement. It is very probable that the "natural cement rock strata" is too thin to be of any commercial value in the manufacture of natural cement.

Paul F. Akin property (Map location 8 B).—The Paul F. Akin quarry is located one-fourth mile northeast of Cave station and about 400 feet north of the Kingston-Cartersville road. The rock consists of the Knox dolomite which is gray heavy-bedded and massive in appearance, fine-grained and partly crystalline. The vertical extent of the outcrop is about 37 feet, of which only about 17 feet is suitable for use in the manufacture of lime. The outcrop along the strike extends only a short distance, due to the covering of chert. The quarry is on the east side of the hill about 25 feet above the valley level. The overburden at the quarry consists of about 15 feet of chert.

The rock is quarried and broken into convenient size for handling by the quarryman. It is then loaded on wheelbarrows and taken to the kiln. One kiln, built of stone and lined with fire brick, has a height of 25 feet. Limestone is added at the top and wood is used in separate fire boxes at the bottom of the kiln. The calcined rock is drawn below the fire boxes. The stone has only been burned for local use.

The following section was made at this locality:

Section of Exposure on Paul F. Akin Property

Sample No.	Unit No.	Description of Units	Thickness feet	Total Thickness feet
333	3	Unconsolidated soil, chert and cherty dolomite	15	25
	2	Cherty dolomite	5	10
	1	Light grayish-blue dolomite	5	5
		Base of stone kiln	0	0

The following analysis shows the composition of the lower 17 feet of the exposure:

Analysis of Dolomite, Paul F. Akin Property

(Sample No. 333; Units No. 1, 2 and lower 7 Feet of Unit No. 3)

Lime (CaO)	29.46
Magnesia (MgO)	18.92
Ferric oxide (Fe_2O_3)	.62
Sulphur trioxide (SO_3)	.00
Phosphorus pentoxide (P_2O_5)	.02
Silica (SiO_2)	4.82
Clay bases	1.04
Soda (Na_2O)	.10
Potash (K_2O)	.18
Loss on ignition	44.84
	100.00

APPENDIX

SPECIFICATIONS

The following specifications for Portland cement by the U. S. Government are taken from the advance chapter mineral resources of the United States Geological Survey, 1911:

Since June, 1911, a committee composed of Government engineers in conference with representative consumers and manufacturers and special committees of the national engineering societies, has been engaged in formulating a single specification for Portland cement to be used by all departments of the Government. This committee has had in view the desirability of an agreement between the specifications in use by the public and those adopted by the Government. At a departmental conference held February 13, 1912, a set of liberal specifications was unanimously adopted, and simultaneously with their publication the following Executive order was issued:

EXECUTIVE ORDER.

It is hereby ordered that all Portland cement that may hereafter be purchased by any department, bureau, office, or independent establishment of the Government, or that may be used in construction work connected with any of the aforesaid branches of the Government service, shall conform in every respect to the specification for Portland cement adopted by the departmental conference at the meeting held at the Bureau of Standards on February 13, 1912, and approved by the heads of the several departments (to be known as the United States Government specification for Portland cement): Provided, however, that such specification may be modified from time to time by any similar departmental conference, with the approval of the heads of the several departments.

WM. H. TAFT.

THE WHITE HOUSE,
April 30, 1912.

UNITED STATES GOVERNMENT SPECIFICATION FOR PORTLAND CEMENT.[1]

SPECIFICATION.

Definition.—1. The cement shall be the product obtained by finely pulverizing clinker produced by calcining to incipient fusion an intimate mixture of properly proportioned argillaceous and calcareous substances, with only such additions subsequent to calcining as may be necessary to control certain properties. Such additions shall not exceed 3 per cent. by weight, of the calcined product.

Composition.—2. In the finished cement the following limits shall not be exceeded:

	Per cent.
Loss on ignition for 15 minutes	4
Insoluble residue	1
Sulphuric anhydride (SO_3)	1.75
Magnesia (MgO)	4

Specific gravity.—3. The specific gravity of the cement shall not be less than 3.10. Should the cement as received fall below this requirement, a second test may be made upon a sample heated for 30 minutes at a very dull red heat.

Fineness.—4. Ninety-two per cent. of the cement, by weight, shall pass through the No. 100 sieve, and 75 per cent. shall pass through the No. 200 sieve.

Soundness.—5. Pats of neat cement prepared and treated as hereinafter prescribed shall remain firm and hard and show no sign of distortion, checking, cracking, or disintegrating. If the cement fails to meet the prescribed steaming test, the cement may be rejected or the steaming test repeated after seven or more days, at the option of the engineer.

Time of setting.—6. The cement shall not acquire its initial set in less than 45 minutes and must have acquired its final set within 10 hours.

Tensile strength.—7. Briquets made of neat cement, after being kept in moist air for 24 hours and the rest of the time in water, shall develop tensile strength per square inch as follows:

	Pounds.
After 7 days	500
After 28 days	600

8. Briquets made up of 1 part cement and 3 parts standard Ottawa sand, by weight, shall develop tensile strength per square inch as follows:

	Pounds.
After 7 days	200
After 28 days	275

9. The average of the tensile strength developed at each age by the briquets in any set made from one sample is to be considered the strength of the sample at that age, excluding any results that are manifestly faulty.

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[1]United States Government specification for Portland Cement: Cir. Bur. Standards No. 33, U. S. Dept. Com. and Labor, May 1, 1912.

10. The average strength of the sand-mortar briquets at 28 days shall show an increase over the average strength at 7 days.

Brand.—11. Bids for furnishing cement or for doing work in which cement is to be used shall state the brand of cement proposed to be furnished and the mill at which made. The right is reserved to reject any cement which has not established itself as a high-grade Portland cement and has not been made by the same mill for two years and given satisfaction in use for at least one year under climatic and other conditions at least equal in severity to those of the work proposed.

Packages.—12. The cement shall be delivered in sacks, barrels, or other suitable packages (to be specified by the engineer), and shall be dry and free from lumps. Each package shall be plainly labeled with the name of the brand and of the manufacturer.

13. A sack of cement shall contain 94 pounds net. A barrel shall contain 376 pounds net. Any package that is short weight or broken or that contains damaged cement may be rejected, or accepted as a fractional package, at the option of the engineer.

Inspection.—14. The cement shall be tested in accordance with the standard methods hereinafter prescribed . In general the cement will be inspected and tested after delivery, but partial or complete inspection at the mill may be called for in the specifications or contract. Tests may be made to determine the chemical composition, specific gravity, fineness, soundness, time of setting, and tensile strength, and a cement may be rejected in case it fails to meet any of the specified requirements. An agent of the contractor may be present at the making of the tests or they may be repeated in his presence.

15. In case of failure of any of the tests, and if the contractor so desires, the engineer may, if he deem it to the interest of the United States, have any or all of the tests made or repeated by the Bureau of Standards, United States Department of Commerce and Labor, in the manner hereinafter specified, all expenses of such tests to be paid by the contractor. All such tests shall be made on samples furnished by the engineer.

After these articles of specification the subject is continued in detail in the Bureau of Standards circular under the heads. "Standard methods of testing," "Methods of chemical analysis." "Interpretation of results," and "Auxiliary specifications," the last being mainly Bureau of Standards specifications for certain apparatus to be used in making tests. Under "Interpretation of results" a number of points are discussed that are of great importance in connection with the specifications quoted above.

INTERPRETATION OF RESULTS.[1]

CHEMICAL.

The composition of normal Portland cement has been the subject of a great deal of investigation, and it can be said that the quantities of silica, alumina,

[1]Circ. Bur. Standards No. 33, U. S. Dept. Commerce and Labor, May 1, 1912.

oxide of iron, lime, magnesia, and sulphuric anhydride can vary within fairly wide limits without materially affecting the quality of the material.

A normal American Portland cement which meets the standard specifications for soundness, setting time, and tensile strength has an approximate composition within the following limits:

	Per cent.
Silica (SiO_2)	19–25
Alumina (Al_2O_3)	5–9
Iron oxide (Fe_2O_3)	2–4
Lime (CaO)	60–64
Magnesia (MgO)	1–4
Sulphur trioxide (SO_3)	1–1.75
Loss on ignition	0.5–3.00
Insoluble residue	0.1–1.00

It is also true that a number of cements have been made both here and abroad which have passed all standard physical tests in which these limits have been exceeded in one or more particulars, and it is equally true that a sound and satisfactory cement does not necessarily result from the above composition.

It is probable that further investigation will give a clearer understanding of the constitution of Portland cement, but at present chemical analysis furnishes but little indication of the quality of the material.

Defective cement usually results from imperfect manufacture, not from faulty composition. Cement made from very finely ground material, thoroughly mixed and properly burned, may be perfectly sound when containing more than the usual quantity of lime, while a cement low in lime may be entirely unsound due to careless manufacture.

The analysis of a cement will show the uniformity in composition of the product from individual mills, but will furnish little or no indication of the quality of the material. Occasional analysis should, however, be made for record and to determine the quantity of sulphuric anhydride and magnesia present.

The ground clinker as it comes from the mill is usually quick setting which requires correction. This is usually accomplished by the addition of a small quantity of more or less hydrated calcium sulphate, either gypsum or plaster of Paris. Experience and practice have shown that an addition of 3 per cent. or less is sufficient for the purpose.

Three per cent. of calcium sulphate ($CaSO_4$) contains about 1.75 per cent. sulphuric anhydride (SO_3), and as this has been considered the maximum quantity necessary to control time of set, the specification limits the SO_3 content to 1.75 per cent.

The specification prohibits the addition of any material subsequent to calcination except the 3 per cent. of calcium sulphate permitted to regulate time of set. Other additions may be difficult or impossible to detect even by a careful mill inspection during the process of manufacture, but as the normal adulterant would be ground raw material, an excess of "insoluble residue" would reveal the addition of siliceous material, and an excess in "loss on ignition" would point to the addition of calcareous material when either is added in sufficient quantity to make the adulteration profitable.

The effect of relatively small quantities of magnesia (MgO) in normal Portland cement, while still under investigation, can be considered harmless. Earlier investigators believed that as magnesia had a slower rate of hydration than lime, the hydration of any free magnesia (MgO) present would occur after the cement had set and cause disintegration.

The effect of magnesia was considered especially injurious when the cement was exposed to the action of sea water. More recent investigation has shown that cement can be made which is perfectly sound under all conditions when containing 5 per cent. of magnesia and it has also been found that the lime in Portland cement exposed to sea water is replaced by magnesia.

The maximum limit for magnesia has been set at 4 per cent., as it has been established that this quantity is not injurious and it is high enough to permit the use of large quantities of raw material available in most sections of the country.

PHYSICAL.

Specific gravity.—The specific gravity is obtained from the formula:

$$\text{Specific gravity} = \frac{\text{Weight of cement in grams.}}{\text{Displaced volume in cubic centimeters.}}$$

The specific gravity of a Portland cement is not an indication of its cementing value. It will vary with the constituents of the cement, especially with the content of iron oxide. Thus the white or very light Portland cements, containing only a fraction of a per cent. of iron oxide, usually have a comparatively low specific gravity ranging from 3.05 to 3.15, while a cement containing 3 to 4 per cent. or more of iron oxide may have a specific gravity of 3.20 or even higher. It is materially affected by the temperature and duration of burning the cement, the hard-burned cement having the higher specific gravity. A comparatively low specific gravity does not necessarily indicate that a cement is underburned or adulterated, as large percentages of raw materials could be added to a cement with a normally high specific gravity before the gravity would be reduced below 3.10.

If a Portland cement fresh from the mill normally has a comparatively low specific gravity, upon aging it may absorb sufficient moisture and carbon dioxide to reduce the gravity below 3.10. It has been found that this does not appreciably affect the cementing value of the material; in fact, many cements are unsound until they have been aged. Thus a redetermination is permitted upon a sample heated to a temperature sufficient to drive off any moisture which might be absorbed by the cement subsequent to manufacturing, but would not drive off any carbon dioxide nor correct underburning in the process of manufacturing the cement.

The value of the specific gravity determination lies in the fact that it is easily made in the field or laboratory, and when the normal specific gravity of the cement is known, any considerable variation in quality due to underburning or the addition of foreign materials may be detected.

Fineness.—Only the extremely fine powder of cement called flour possesses appreciable cementing qualities and the coarser particles are practically inert. No sieve is fine enough to determine the flour in a cement, nor is there any other means of accurately and practically measuring the flour. Some cements grind easier than others; thus, although a larger percentage of one cement may pass the 200-mesh sieve than another, the former may have a smaller percentage of actual flour due to the difference in the hardness and the character of the clinker and the method used in grinding. Thus the cementing value of different cements can not be compared directly upon their apparent fineness through a 200-mesh sieve. With cement from the same mill, with similar clinker and grinding machinery, however, it is probable that the greater the percentage which passes the 200-mesh sieve the greater the percentage of flour in that particular cement.

Normal consistency.—The quantity of water used in making the paste from which the pats for soundness, tests of setting, and the briquets are made is very important and may vitally affect the results obtained. The determination consists in measuring the quantity of water required to bring a cement to a certain state of plasticity.

In determining the normal consistency by the ball method, after mixing the paste it should be formed into a ball with as little working as possible and a new batch of cement should be mixed for each trial paste. In order to obtain just the requisite quantity of paste to form a ball 2 inches in diameter, a measure made from a pipe with a 2-inch inside diameter cut 1⅛ inches long would be found convenient. The section of pipe should be open at both ends, so that it can be pushed down into the paste on the mixing table and the excess paste cut off with a trowel. The appearance of the ball, using the correct percentage of water for normal consistency as compared with a less and greater quantity of water, is [illustrated in the Bureau of Standards circular].

Mixing.—The homogeneity of the cement paste is dependent upon the thoroughness of the mixing, and this may have considerable influence upon the time of setting and the strength of the briquets.

Soundness.—The purpose of this test is to detect those qualities in a cement which tend to destroy the strength and durability. Unsoundness is usually manifested by a change in volume, which causes cracking, swelling, or disintegration. If the pat is not properly made, or if it is placed where it will be subject to any drying during the first 24 hours, it may develop what are known as shrinkage cracks, which are not an indication of unsoundness and should not be confused with disintegration cracks. * * * No shrinkage cracks should develop after the first 24 or 28 hours. The failure of the pats to remain on the glass nor the cracking of the glass to which the pat is attached does not necessarily indicate unsoundness. In molding the pats the cement paste should first be flattened on the glass and the pat formed by drawing the trowel from the outer edge toward the center. * * *

Time of setting.—The purpose of this test is to determine the time which elapses from the moment water is added until the paste ceases to be plastic and the time required for it to obtain a certain degree of hardness. The determination of the "initial set," or when plasticity ceases, is the more important, as a disturbance of the material after this time may cause a loss of strength, and thus it is important that the mixing and molding or the incorporating of the material into the work be accomplished within this time. The time of setting is usually determined upon one of the pats which is to be used for the soundness test, the top surface being flattened somewhat. * * * In using the Gillmore needles care should be taken to apply the needles in a vertical position and perpendicular to the surface of the pat. An arrangment [has been perfected] for mounting the Gillmore needles so that they are always perpendicular to the surface of the pat. The rate of setting and hardening may be materially affected by slight changes in temperature. The percentage of water used in gaging and the humidity of the moist closet in which the test pieces are stored may also affect the setting somewhat.

Tensile tests.—Consistent results can only be obtained by exercising great care in molding and testing the briquets. The correct method of filling the mold [is illustrated in the circular]. In testing, the sides of the briquet and the clips should be thoroughly cleaned and free from grains of sand or dirt, which would prevent a good bearing, and the briquet should be carefully centered in the clips so as to avoid cross strains. It may be considered good laboratory practice if the individual briquets of any set do not show a greater variation from the mean value than 8 per cent. for sand mixtures and 12 per cent. for neat mixtures.

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