GEOLOGICAL SURVEY OF GEORGIA

S. W. McCALLIE, State Geologist

BULLETIN No. 21

A REPORT

ON THE

LIMESTONES AND MARLS

OF THE

COASTAL PLAIN

OF

GEORGIA

BY

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ATLANTA, GA.

THE BLOSSER COMPANY

1916

LIMESTONE QUARRY ON GRADY PROPERTY, 2 MILES SOUTH OF TIVOLA, HOUSTON COUNTY.

LETTER OF TRANSMITTAL

GEOLOGICAL SURVEY OF GEORGIA,
ATLANTA, JUNE 1, 1916.

To His Excellency, NAT. E. HARRIS, *Governor and President of the Advisory Board of the Geological Survey of Georgia.*

SIR: I have the honor to transmit herewith the report of Mr. J. E. Brantly, Assistant State Geologist, on the Limestones and Marls of the Coastal Plain of Georgia, to be published as Bulletin No. 21, of this Survey.

Very respectfully,

S. W. McCALLIE,
State Geologist.

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The State of Georgia is divisible into five distinct physiographic provinces—the Cumberland Plateau, the Appalachian Valley, the Appalachian Mountains, the Piedmont Plateau, and the Coastal Plain—each of which can be further divided into lesser districts. Geologically the State is divisible into three provinces—the area of Paleozoic strata which includes the Cumberland Plateau and the Appalachian Valley, the metamorphic and igneous rocks of the Appalachian Mountains and the Piedmont Plateau, and the Cretaceous and later strata of the Coastal Plain. A large percentage of the Paleozoic rocks is limestone and dolomite, while marble (crystalline limestone) is found along the western edge of the Appalachian Mountains and in a few localities in the northern part of the Piedmont Plateau area. These deposits have been described by T. Poole Maynard in the report on "Limestone and Cement Materials of North Georgia," Bulletin Georgia Geological Survey No. 27, 1912. The limestones of the Coastal Plain are discussed in this report.

COASTAL PLAIN

PHYSIOGRAPHY

The Coastal Plain of Georgia includes all of that portion of the State south of the "Fall Line," an irregular line running through Columbus, Macon, Milledgeville and Augusta, and comprises an area of approximately 35,000 square miles, more than half the area of the State.

The region is a comparatively low plain sloping gently to the southeast. The highest elevations are along the Fall Line where they vary from 500 to 700 feet above sea level. A slope of 3 or 4 feet per mile is general from this line to the Atlantic Coast. Although, when compared with the topography of those areas north of the Fall Line, the surface relief is slight it is not without distinctive features. The most notable topographic feature is that belt along the Fall Line known as the Fall Line Hills. This belt extends entirely across the State with a width varying from 30 to 40 miles, with the Fall Line the northern boundary. This area has a maximum relief of about 350 feet, considering the larger streams as the base, which shows a much more mature topography than the portion of the plain to the south. Cretaceous sands and clays, the principal materials underlying the area, are easily eroded and have caused deep gullies and washes throughout the belt. To the north the Fall Line Hills merge into the Crystalline area and to the south into the Dougherty Plain, another distinctive topographic feature of the Coastal Plain.

The Dougherty Plain is a level to rolling area extending from the southwestern corner of the State to the Oconee River a few miles north of Dublin. Its greatest width is from Fort Gaines southeastward, about 60 miles, while it comes to a point at its eastern extremity. These are the limitations given by Otto Veatch, formerly Assistant State Geologist, but it seems that the belt should be extended to the Savannah River, including Sandersville, Louisville, and Waynesboro.

The Altamaha Upland lies to the southeast of the Dougherty Plain with its southeastern border along a line extending from the southwestern corner of the Okefenokee Swamp to the Savannah River a few miles below the mouth of Briar Creek, Screven County. Northwest of a line from Valdosta to the above point on the Savannah River the elevations of the Dougherty Plain and the Altamaha Upland are about the same, considering the general slope toward the

Atlantic seaboard—300 to 450 feet along the northern edge of the former belt and 200 to 250 feet along the Valdosta-Briar Creek line. The surface material over both districts as well as the general topography is very similar, therefore it seems that the two belts should be combined as one subdivision of the Coastal Plain.

The Okefenokee Plain lies to the southeast of the Altamaha Upland, paralleling the coast about 30 miles inland, while the Satilla Coastal Lowland occupies this 30-mile belt along the Atlantic Coast.

In the southwestern part of the State there is a district including the southern portions of Decatur, Grady, Thomas, Brooks, Lowndes, and Echols counties to which the name Limesink region has been given because of the numerous ponds, lakes, and caverns due to "lime sinks." There are comparatively few surface streams in this belt, most of the meteoric waters being carried off through subterranean channels. Occasional well-like sinks disclose the water in these underground streams.

STRUCTURE

The strata over the larger portion of the Coastal Plain dip to the southeast while along the southern border of the State, west of the Okefenokee Swamp, they have a slight southward dip. The strata of Cretaceous age have the greatest dip—a few feet to 30 or 40 feet per mile—while the beds of the youngest formations are nearly level. The early Eocene has a probable average dip of 12 to 15 feet per mile and the late Eocene 6 to 10 feet per mile, while the dip of the more recent beds is less. Two slight anticlines have been recognized by Veatch—the Chattahoochee Anticline, with its axis along the Chattahoochee River from Columbus into Florida, and the Withlacoochee Anticline, which includes the drainage basins of the Allapaha, Withlacoochee and Ochlockonee rivers.

GEOLOGY

THE CRETACEOUS SYSTEM[1]

The Cretaceous deposits of Georgia include representatives of both the Lower and Upper Cretaceous series, which are divided as follows:

- Upper Cretaceous.
  - Ripley formation.
    - Providence sand member.
    - Marine beds.
    - Cusseta sand member.
  - Eutaw formation.
    - Tombigbee sand member.
    - Sands, clays and marls, chiefly of marine origin.
- Unconformity.
- Lower Cretaceous. Arkose sands and clays. Not differentiated.

LOWER CRETACEOUS SERIES

Beds of Lower Cretaceous age outcrop in an extremely irregular belt, 2 to 20 miles in width, extending from the vicinity of Columbus on the Chattahoochee River to the vicinity of Augusta on the Savannah River. These deposits rest unconformably upon ancient crystalline rocks of probable pre-Cambrian age. The surface of these basement rocks is very uneven in detail, but, in general, slopes south and southeast beneath the Lower Cretaceous deposits at the rate of 30 to 75 feet per mile, according to calculations from well borings at several places. Between the Chattahoochee and Ocmulgee rivers the Lower Cretaceous is overlain unconformably by the Upper Cretaceous strata, while northeastward from the Ocmulgee River to the Savannah River strata of Eocene age rest unconformably upon the Lower Cretaceous beds. These last mentioned strata have a thickness of from 350 to 600 feet. The strike varies from due east at Columbus to N. 65° E. northeast of Macon, while the dip probably averages from 25 to 30 feet per mile to the south and southeast.

The Lower Cretaceous deposits consist predominantly of arkosic sand, with a considerable amount of clay in the form of interbedded

[1] Abstracted from Veatch and Stephenson, Geology of the Coastal Plain of Georgia: Bull. Ga. Geol. Survey, No. 26, 1911, pp. 66-215.

lenses. In places the sands have been indurated and form friable sandstones. The lenses of clay vary widely in lithologic character, shape and extent; in thickness they range from 1 inch or less to 40 feet, and in horizontal extent from a few square feet to many acres. Many of the clays are very white and approach kaolin in composition. They are worked extensively east of Macon for paper filler and various ceramic products. Bauxite occurs locally, in the kaolin beds, in Wilkinson County.

UPPER CRETACEOUS SERIES

The Upper Cretaceous series in Georgia is exposed between the Chattahoochee and Ocmulgee rivers, outcropping for a distance of about 55 miles along the former stream and for a few miles along the latter. These formations rest unconformably upon the Lower Cretaceous and are overlain unconformably by deposits of Eocene age. The total thickness of the Upper Cretaceous beds is estimated to be about 1500 feet. The strike varies from nearly due east just east of the Chattahoochee River to N. 60°-75° E. as the Ocmulgee River is approached. The dip ranges from 20 to 40 feet per mile to the south and southeast.

The deposits of Upper Cretaceous age are composed mainly of unconsolidated sands, clay lenses, calcareous sand, and marl. The clay frequently resembles the kaolins of the Lower Cretaceous and locally are of commercial value. Some of the marls may be of value for local agricultural uses.

TERTIARY SYSTEM

EOCENE SERIES

MIDWAY FORMATION[1]

The Midway formation outcrops in a relatively narrow northeast-southwest belt, extending from Fort Gaines on Chattahoochee River to Montezuma on Flint River and thence for a short distance into Houston County. On the Chattahoochee the formation has a width

[1] Abstracted from Stephenson, L. W., and Veatch, Otto, Underground waters of the Coastal Plain of Georgia: Water Supply Paper, U. S. Geol. Survey, No. 341.

of about 8 miles, on the Flint a width of about 15 miles, and between the two rivers an average width of 8 to 10 miles. The formation appears at the surface over parts of Clay, Quitman, Stewart, Randolph, Marion, Schley, Webster, and Macon counties and extends eastward from Flint River probably as far as Myrtle on the Perry branch of the Central of Georgia Railway in Houston County. No occurrence is known east of Ocmulgee River, beyond which the formation is probably overlapped by higher Eocene formations.

The Midway formation rests unconformably upon the Upper Cretaceous and is unconformably overlain by the Wilcox formation. It consists of sands, clays, marls, and limestones, having a thickness estimated at 200 to 400 feet. The dip is from 20 to 30 feet per mile to the southeast.

The limestones which are confined chiefly to the upper part of the formation occur in beds from 2 to 25 feet in thickness. These calcareous deposits seem to be locally developed. At Browns Mill near Fort Gaines, Clay County, a soft, white limestone is exposed for a thickness of 20 feet immediately beneath the Wilcox beds. In the northern part of the same county, 6 miles south of Hatcher Station, there is an excellent exposure of hard, comparatively pure limestone that in years past was used for the manufacture of lime. Another exposure of this same type of limestone underlain by an arenaceous limestone occurs at Greer Cave, 9 miles north of Cuthbert, Randolph County. Both of these varieties of the limestone are exposed on the Flint River near Montezuma, Macon County.

WILCOX FORMATION[1]

The Wilcox formation outcrops in a belt extending northeastward from the vicinity of Fort Gaines on Chattahoochee River probably to Flint River in the northeastern part of Sumter County; east of the Flint it has not been certainly recognized. The width of the outcrop is believed to average not more than 5 or 6 miles. The formation is

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[1] Abstracted from Stephenson and Veatch's report on the underground waters of the Coastal Plain of Georgia: Water Supply Paper, U. S. Geol. Survey, No. 341.

to some extent overlapped and concealed by deposits of later Eocene.

The Wilcox formation includes the strata lying unconformably between the Midway formation and the Claiborne group. It is made up of sandy, glauconitic shell marl, dark colored, laminated, largely lignitic sandy clay, in places consolidated into mudstone, and often dark or gray glauconitic and lignitic sand. In Schley and Macon counties and in the vicinity of Andersonville, the strata, which might be referred to this formation on the basis of geographic position, are mainly red and vari-colored sands with massive beds of very pure, white clay in the nature of sedimentary kaolin, bearing little resemblance to the strata on Chattahoochee River.

Langdon[1] estimated the thickness of the formation on Chattahoochee River at 402 feet; but this is excessive, for at Fort Gaines the thickness is certainly not more than 60 or 75 feet. A natural exposure of the formation at Peterson Hill, 4½ miles northwest of Cuthbert reveals about 100 feet of strata. There is no positive proof that strata of Wilcox age outcrop on Flint River, where the formation may be entirely overlapped by the Claiborne group, but if the strata between the Midway and the McBean or Vicksburg formations at Dripping Bluff, 9 miles south of Oglethorpe, are Wilcox, the thickness of the latter is perhaps 100 feet. The maximum thickness at any place in the area of outcrop probably does not exceed 150 or 200 feet.

The area underlain by the formation is small and presents no notable physiographic features. The topography of the area is rather broken and hilly, resembling that of the area to the north underlain by the Midway formation.

The Wilcox strata strike about N. 55° E. and dip southeastward at a rate that cannot be accurately estimated but that is probably less than 30 feet to the mile over the area of outcrop and is perhaps less than half as much under cover of the later formations to the south.

[1] Langdon, D. W., Geology of the Coastal Plain of Alabama: Ala. Geol. Survey, 1894.

CLAIBORNE GROUP

The Claiborne group in Georgia has been divided by Veatch and Stephenson[1] into two formations, the McBean at the base and the Barnwell overlying. The two formations are given as occurring over that portion of the State between the Oconee and Savannah rivers mapped as Claiborne and "Undifferentiated Eocene" in this report. They cover portions of Wilkinson, Twiggs, and Houston counties. A narrow belt is also described as extending from Houston County to the Chattahoochee River below Fort Gaines.

During the field work for this report and work done by Shearer, Assistant State Geologist, for the reports on fullers earth and bauxite, certain conclusions have been reached that differ widely from those of the above mentioned authors. However, sufficient data were not collected to do more than show the necessity for closer investigation. This point is brought out in the description of the Jackson formation in this report.

The Congaree clay member of the McBean formation of previous reports, which extends from the Ocmulgee River eastward to the Savannah River, together with the fossiliferous strata immediately underlying, seems to be a continuation of the Jackson limestone and fullers earth of Houston County. The so-called Barnwell sands which overlie these beds seem to be equivalent to the residual sands called Vicksburg in Veatch and Stephenson's report, which are here described as Claiborne and "Undifferentiated Eocene and Oligocene." The residual sands covering the central and northern portions of Houston County also seem to belong to the last mentioned series of beds.

The narrow belt of outcrops of Claiborne strata which extends southwestward from Houston County to the Chattahoochee River was not studied during the field work for this report, hence nothing is known about it other than that of previously published reports.

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[1] Veatch, Otto, and Stephenson, L. W., Geology of the Coastal Plain of Georgia: Bull. Ga. Geol. Survey, No. 26, 1911, pp. 235-296.

Between the Oconee and Savannah rivers there are beds of sand, clay, fossiliferous flint, limestone, and marls which, according to fossil collections made by various persons, are referable to the Claiborne group. These exposures cover a comparatively small portion of the section in which they occur. Sufficient work was not done to accurately separate on a map these outcrops from those of the overlying formation nor have the contacts been definitely determined, consequently on the map accompanying this report the several beds are mapped as Claiborne and "Undifferentiated Eocene."

The Claiborne group lies between the Wilcox formation below and the Jackson group above. A well-marked unconformity was recognized between the Wilcox and the Claiborne formations by Veatch and Stephenson. No exposures show definitely an unconformity between the Claiborne and the Jackson. There are, however, certain conditions which indicate unconformable relations.

The formation consists of sands, clays, marls, limestones, and fossiliferous flint. The first three occur mainly west of the Flint River, while the last two, together with marls, make up the larger portion of the outcrops east of the Oconee River.

The thickness of the Claiborne group east of the Oconee River has been estimated to be 400 to 500 feet. This includes those strata which are evidently of later age. Subtracting 150 feet for the latter beds, it leaves 250 to 350 feet, which is probably about the thickness of the Claiborne east of the Oconee River. The thickness of the group has been estimated to be 250 to 300 feet on the Chattahoochee River.

The strata dip southward and southeastward at the rate of 8 to 15 feet per mile.

JACKSON GROUP

The name Jackson group, or Jackson formation, is so-called from the type locality near Jackson, Mississippi. Veatch and Stephenson used the latter title for the group of beds in Georgia in their report on the Geology of the Coastal Plain. More recent work by C. Wythe Cooke of the U. S. Geological Survey, has shown that beds originally correlated with the Vicksburg formation are in reality of Jackson age. These deposits are exposed along the Flint River from the upper part of Crisp County to Bainbridge, Decatur County. The outcrops near Bainbridge, Vaughan correlated with the Ocala formation of Florida which Cooke[1] has subsequently determined to be the upper formation of the Jackson group. Based upon this work, Dr. Vaughan of the U. S. Geological Survey, has suggested in a letter to McCallie that the name "Jackson formation" be changed to "Jackson group," since it is divisible into at least two formations. This suggestion is followed in this report. The exposures near Albany and between Albany and Bainbridge are referred to as belonging to the Ocala formation. The entire area underlain by this group has not yet been studied thoroughly, therefore, it is indicated on the accompanying map as "Undifferentiated Eocene and Oligocene," except the area described as Jackson by Stephenson and Veatch and portions of Twiggs and Wilkinson counties formerly described as Claiborne.

The total area covered by those outcrops which are known to be of Jackson age is comparatively small. There are, however, two large areas which have heretofore been considered to be within the surface terranes of the Claiborne group and Vicksburg formation in which the exposed strata may be of Jackson. The recognized Jackson area extends westward from Johnson through Wilkinson, Twiggs, Bleckley, Pulaski, Houston, Macon, Dooly, and Sumter counties and for a short distance into Crisp County.

R. S. Bassler[2] of the U. S. National Museum, has discovered Bryozoa of Jackson age in specimen of white marl from above the *Ostrea georgiana* bed at Shell Bluff, Savannah River, collected by Sloan[3] from stratum "b" of the latter's section.

The *Ostrea georgiana* bed is exposed in several places along the Savannah River and between this stream and the Oconee River, with

[1] Cooke, Charles Wythe, the age of the Ocala limestone: Prof. Paper, 95-I, U. S. Geol. Survey, 1915.

[2] Oral communication to Dr. Vaughan.

[3] Sloan, Earle, Catalogue of the Mineral Localities of South Carolina: S. C. Geol. Survey, Ser. 4, Bull. 2, 1908, p. 271.

fullers earth immediately overlying. Red and mottled residual clay-sands overlie the fullers earth. This residual material covers the greater portion of that section between the two above mentioned rivers formerly mapped as Claiborne. Hence, it seems that the district is within the terrane of the Jackson formation. There are numerous exposures, along streams, of fossiliferous beds beneath the *Ostrea georgiana* bed that are of probable Claiborne age. This is borne out by the identification of fossils from numerous collections made within recent years.

Dr. Cooke and the writer made a number of collections of fossils from the limestone strata exposed along the Flint River from Crisp County to the Florida line. Cooke has determined the age of the limestone to be Jackson from near the center of Crisp County to Bainbridge, Decatur County. The results of this work are not as yet ready for publication, therefore the strata are mapped "Undifferentiated Eocene and Oligocene."

Strata of Jackson age have been determined on Ichawaynochaway Creek, 1½ miles below Cordray Mill, Calhoun County,[1] and on Chattahoochee River near Alaga, Alabama.[2] There is also a small, isolated area at Rich Hill near Roberta, Crawford County.

The Jackson group comprises the uppermost Eocene strata exposed in Georgia, lying between the Claiborne group below and the Vicksburg formation (Oligocene) above. The line of division between the Jackson group and the Claiborne group has not been definitely determined, therefore, it cannot be said whether deposition was interrupted or continuous between the older and the younger formations. If the 20-foot bed of sand immediately overlying the Lower Cretaceous in the pits of the Georgia Kaolin Company near Dry Branch, Twiggs County, is Claiborne, the very slight unconformity is indicative of an erosion period between deposition of the two formations. However, this unconformity has not been definitely

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[1] Veatch and Stephenson, Geology of the Coastal Plain of Georgia: Bull. Ga. Geol. Survey, No. 26, 1911, p. 299.

[2] Langdon, D. W., Report on the Coastal Plain of Alabama: Ala. Geol. Survey, 1898, p. 383.

recognized. It is possible that the irregular surface is due to wave action over the shallow water in which the sand was laid down. In this case the bed probably belongs to the Jackson group, which means that the Claiborne group is entirely overlapped.

Lithologically, the Claiborne and the Jackson are very closely related. Crider[1] states that in Alabama "even where the two formations have been best studied there seems to be a gradation in both fossils and the stratigraphy from the upper Claiborne to the lower Jackson." In this State, the Jackson has not been described as a separate group or formation and very little has been published regarding its relationship to the underlying Claiborne. From the descriptions by Langdon,[2] in the report on the Geology of the Coastal Plain of Alabama, a close relationship, both lithologically and faunally, is evident. No unconformities between the two formations are mentioned.

In exposures where the Jackson group and Vicksburg formation are in contact, no evidence of unconformable relations are visible. This is well shown on the Ocmulgee River near Hawkinsville, Pulaski County, where the lower beds are Jackson and the upper beds probably Vicksburg.

At Rich Hill near Roberta, Crawford County, according to Veatch and Stephenson,[3] the Jackson rests directly on the Lower Cretaceous. Their section shows a bed of sand, which they put in the Jackson, between the Jackson limestone and the Cretaceous clay. This being the case, then, it is possible that the bed of sand occupying the same position at the Georgia Kaolin Company's pits near Dry Branch is also a part of the Jackson. The marine deposited material in the Jackson here indicates that the group originally overlapped a portion of the Crystalline rocks to the northward.

The Jackson group consists of white to cream colored, massive and thin-bedded, highly fossiliferous limestone, fossiliferous clays or

[1] Crider, A. F., Geology and Mineral Resources of Mississippi: Bull. U. S. Geol. Survey, No. 283, 1906, pp. 33 and 34.
[2] Op. Cit., pp. 111, 128, 381, and 383.
[3] Op. cit., pp. 297, 299-300.

marl, fullers earth, and beds of other clays. The limestone beds which occur at or near the base of the Jackson vary from 15 feet in thickness in the northern part of Twiggs County to 45 feet at the quarry, 2 miles south of Tivola, Houston County. The overlying fullers earth has a thickness of 90 feet[1] in the northern part of Twiggs and in Wilkinson counties and is about 50 feet in Houston County. Together with the other beds the total thickness of the group varies from 100 to 125 feet between the Flint and Oconee rivers. At Americus, Sumter County, a well record shows the group to be 157 feet thick. If, as is now supposed, the limestone exposures along the Flint River from Crisp County to and below Newton, Baker County, belong to the Jackson group, the thickness is probably greater through this section than that given above.

The more highly fossiliferous bed of limestone in the group is made up almost entirely of Bryozoa with scattered Pecten, Orbitoides, Periarchus and other fossils. This bed is the lower limestone stratum and is immediately overlain by a thinner bed containing a greater variety of fossils among which are species of Bryozoa, Lunulites, Flabellum, Endopachys, Dentalium, Leda, Crassatellites and others. Turritella is rather common in all of the limestone strata. Some fragments of the whale-like mammal Zeuglodon (Basilosaurus), a characteristic Jackson fossil, have been found in Georgia. Sharks' teeth are rather common in the fullers earth beds in certain localities. *Ostrea georgiana* is common in the bed underlying the fullers earth of the Savannah River.

That portion of the Coastal Plain between the Oconee and Flint rivers immediately underlain by the Jackson group is characterized by a comparatively rugged topography. Prominent escarpments occur along practically all of the larger streams with the limestone outcropping along the lower edges of the slopes. As would be expected the scarps are usually along the southeast sides of the streams; this is due to the fact that the strata dip to the southeast and the ten-

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[1] Shearer, H. K., Assistant State Geologist of Georgia: unpublished notes, 1915.

dency of the streams is to work along the strike of the beds. The surface relief, considering the Ocmulgee River as the base, is about 250 feet.

The strata are so nearly horizontal that the dip cannot be detected in any one exposure. By recording the elevations of the contacts of two beds in one exposure and of the same beds in another outcrop the dip of the strata has been calculated to average between 5 and 8 feet per mile. Neither regional nor local disturbances of the strata have been detected, other than an occasional small sink due to the solution of the limestone and the caving of the overlying material.

From an economic standpoint the Jackson group is one of the most important series of beds in the Coastal Plain. A large portion of the workable limestone deposits in the southern portion of the State belong to this group as well as the fullers earth deposits of Twiggs and Wilkinson counties, which are among the most extensively worked in the United States and furnish an excellent grade of material.

DETAILED DESCRIPTIONS OF THE JACKSON GROUP OF EXPOSURES

The object of the detailed descriptions of the exposures which follow is mainly to show the distribution of strata of Jackson age in the district between the Savannah and Oconee rivers, throughout Wilkinson and Twiggs counties, in the southern part of Bibb County, the western part of Dooly County and along the Flint River. It is not within the scope of this, an economic report, to determine definitely the horizon of each of the numerous exposures studied. However, it seems expedient to give here brief descriptions of a few of the more prominent exposures, in the localities mentioned above, to show the necessity of closer investigation before the relationship between the Claiborne and Jackson groups and the Jackson group and Vicksburg formation can be as definitely determined.

Burke County

Shell Bluff.—The strata exposed at Shell Bluff, on the Savannah River, 40 miles below Augusta, have been studied by various geologists and paleontologists during the past century, few of whom have exactly agreed as to the stratigraphic position and age of the beds. The most recent published opinions are by Veatch, Stephenson, and Vaughan,[1] who determined the strata to be of Claiborne age. More recent studies of the fossil collections by Vaughan and Bassler have shown Bryozoa of Jackson age above the *Ostrea georgiana* bed. This bed occurs from 80 to 100 feet above the level of the river.[2]

At Griffins Landing, 16 miles by river below Shell Bluff, the *Ostrea georgiana* bed is immediately overlain by fullers earth.

Keys Mill (map locality Bu-9).—The following section was observed at Keys Mill, on Brushy Creek, 2½ miles northwest of St. Clair:

Section at Keys Mill

	Feet
Eocene.	
4. Residual red sands	20
Jackson group.	
3. Fullers earth	8
2. Large oyster shells in arenaceous fullers earth	7
1. Covered	5
Pond level	

The residual sands of the upper bed are similar in every respect to those which cover the larger portion of this section of the State. The fullers earth of bed No. 3 is apparently the same as that at Griffins Landing and near Louisville. The oyster shell bed beneath the fullers earth is apparently a continuation of the *Ostrēa georgiana* bed at Shell Bluff and near Louisville. The elevation of the top of bed No. 2 is 270 feet by aneroid reading.

One mile south of Keys Mill silicified oyster shells were seen in the red sands at an elevation of 320 feet by aneroid barometer reading.

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[1] Report on the Geology of the Coastal Plain of Georgia: Bull. Ga. Geol. Survey, No. 26, 1911, pp. 243-248.

[2] Op. cit., p. 247.

Jefferson County

Near Louisville.—A bed of *Ostrea georgiana* shells in calcareous fullers earth is exposed on the south side of the Ogeechee River, 200 yards up-stream from Cowarts Bridge, 2½ miles south of Louisville. The bed is entirely similar to those at Griffins Landing and Keys Mill. A collection was made at this exposure by S. W. McCallie, State Geologist, and the oyster identified by Vaughan.

Up Rocky Comfort Creek from the bridge one mile north of Louisville, there are several exposures of fullers earth near the water's edge and 35 to 40 feet above. The lowest of the exposures is at least several feet above the oyster shell bed on the Ogeechee River south of Louisville. Red, yellow and white, argillaceous sands occur above the fullers earth.

Baldwin County

Stevens Pottery.—H. K. Shearer collected Bryozoa (Rich Hill horizon, identified by Bassler) from a bed of gray, fossiliferous marl which immediately overlies Cretaceous kaolin in the pits of the Stevens Bros. Company. Fullers earth overlies the Bryozoa bed. The section and material bears a very close resemblance to the exposures in the northern part of Twiggs County and on the Carswell property in Wilkinson County.

Wilkinson County

Near Toomsboro.—H. K. Shearer, Assistant State Geologist of Georgia, has furnished the following section of exposures on the property of Dr. N. T. Carswell, 3 miles west of Toomsboro:

Section on Carswell Property, 3 Miles West of Toomsboro

	Elev.
Eocene.	
5. Residual sands cap high hills.	
Jackson group.	
4. Fullers earth	300
3. Hard and soft, yellow, argillaceous, bryozoan limestone	270-290
Unconformity	250

GEOLOGIC MAP OF THE COASTAL PLAIN OF GEORGIA

BY OTTO VEATCH AND L. W. STEPHENSON, UNDER THE DIRECTION OF T. WAYLAND VAUGHAN,

WITH ALTERATIONS OF THE EOCENE SERIES AND THE DISTRIBUTION OF LIMESTONE BY J. E. BRANTLY, ASSISTANT STATE GEOLOGIST

1916

Cretaceous.
2. Bauxite, lenses.
1. Kaolin and kaolinic sands.

Bassler determined Bryozoa of the Rich Hill horizon of the Jackson in a collection from bed No. 3.

Other exposures of a similar nature occur throughout the county.

Crawford County

Rich Hill.[1]—One of the most interesting localities of the Jackson formation is at Rich Hill, 5 miles southeast of Roberta. The hill rises about 150 feet above the small valley on the south side, and is a conspicuous topographic feature. This is an isolated exposure and indicates that the northward extension of the group was formerly much greater than at present. The hill is capped by brilliant red sand, probably referable to the Jackson group, overlying the calcareous beds undoubtedly belonging to the Jackson; the latter rests upon white clays and sands of the Lower Cretaceous. The hill is deeply trenched by erosion gullies in which the strata are laid bare. The following section was made from exposures in the gullies on the south side:

Section at Rich Hill

	Feet	In.
Eocene.		
Jackson group. (?)		
13. Brilliant red sand, capping the hill and forming "creep" on the upper slopes	30	
Jackson group.		
12. Purplish and yellow sand, containing thin clay laminæ	12	
11. Greenish, laminated clay, thin lignitic partings	4	
10. Plastic, calcareous clay with fossils	0	6
9. Drab, jointed laminated clay, with sand partings	6	
8. Fossiliferous, nodular, calcareous layer	0	12
7. Drab, soft, laminated clay with fossils; contains nodular, calcareous layers	12	
6. Limestone, generally soft and friable but in places hard and compact; in places it is a bryozoan marl so soft that it may be scraped up with the		

[1] Reprint from Veatch and Stephenson, Geology of the Coastal Plain of Georgia: Bull. Ga. Geol. Survey, No. 26, 1911, pp. 299-300.

	hands. Fossils chiefly Bryozoa, *Pecten perplanus*, and Mortonia sp.; fish teeth are also abundant in places	20
	5. Brown and yellow unconsolidated sand which in places is replaced by limestone	12
Lower Cretaceous.		
	4. White, micaceous clay; maximum	10
	3. White, cross-bedded clayey sand	10
	2. White, micaceous clay	3
	1. Coarse, white sand	10

List of Fossils from Rich Hill

(Identified by T. W. Vaughan)

Mortonia sp.
Plejona sp.
Calyptrea aperta (Solander)
Ostrea georgiana Conrad
Pecten perplanus Morton
Pecten, probably P. nuperus (Conrad) young and poor specimens
Venericardia sp.
Lucina sp., (found also 5½ miles south of Perry)
Panopæa sp.
(The Mortonia referred to above is also found at Castle Hayne and Wilmington, N. C., and 9 miles east of Waynesboro, Burke Co., Ga.)

Twiggs County

Dry Branch.—There is an exposure of Jackson strata in the pits of the Georgia Kaolin Company, 2 miles east of Dry Branch. A comparison of the section given below with that at Rich Hill, Crawford County, given above, shows a very close similarity between the two exposures. Another outcrop of the calcareous Jackson bed occurs in a gully one-half mile southeast of the Georgia Kaolin Company. This exposure was studied by Veatch and Stephenson[1] and the determination of the fossils collected by Vaughan.

Section at Georgia Kaolin Company's Pits

	Feet	In.
8. Top soil, reddish, sandy clay	2	
Eocene.		
Jackson group.		
7. Gray fullers earth (weathered), blackish, probably organic, stains in thin partings	18	

[1] Veatch, Otto, and Stephenson, L. W., Geology of the Coastal Plain of Georgia: Bull. Ga. Geol. Survey, No. 26, 1911, p. 304.

6. Whitish, highly fossiliferous sandy fullers earth; Bryozoa, Orbitoides, *Pecten perplanus* Morton...	6	
Claiborne?		
5. Coarse grained, brownish sand, black at base.......	1	6
4. Wavy, thin-bedded, coarse, red, gray, and black sand	2	6
3. Grayish-yellow, coarse grained sand...............	12	
2. Hard to soft fossiliferous sand, containing clay pebbles	2	
Unconformity.		
Lower Cretaceous.		
1. White kaolin, sand said to underlie...............	20	

Dr. C. Wythe Cooke makes the following statement in a letter to the writer regarding collections sent him from this locality: "The calcareous material (bed No. 6) is Jacksonian." He recognized *Mesalia vetusa* (Conrad) in the collection from bed No. 2 and places the horizon as "probably Claiborne." A very doubtful unconformity exists between beds Nos. 5 and 6.

Vaughan identified the following list of fossils from the 15-foot exposure of "soft, white, argillaceous marl" one-half mile southeast of the Georgia Kaolin Company's pits, and, upon the evidence furnished by the species, determined the horizon to be Jacksonian:[1]

List of Fossils from Ravine One-half Mile Southeast of the Georgia Kaolin Company's Pits (Vaughan)

Platytrochus stokesi (Lea)
Mortonia
Leda multilineata Conrad
Pecten perplanus Morton
Protocardia
Tellina
Corbula densata Conrad
Bryozoa (very numerous)

Lowe Wall Property (map locality T-1).—There is on the Lowe Wall place, 2 miles south of Pikes Peak Station, a 12-foot exposure of soft, cream colored, limestone composed almost entirely of fossils. This stone is similar both lithologically and faunally to that of the various other exposures of Jackson limestone in this and the contiguous counties. Black, tough clay-soil, probably derived from fullers earth, overlies the limestone. Cooke identified Bryozoa, *Periarchus*

[1] Op. cit.

pileus-sinensis (Rav.) and *Pecten perplanus* Morton in a collection from this exposure.

Map locality T-2.—A similar exposure to the above occurs on the south side of an abandoned railroad cut 3½ miles southeast of Stony Creek church. The following section is descriptive of the strata exposed:

Section 3 1/2 Miles Southeast of Stony Creek Church

Jackson group.	Feet
3. Gray fullers earth, topped by tough, black clay-soil.	6
2. Soft, white, highly fossiliferous limestone with thin, medium hard, layers. Lower 2 feet argillaceous..	16
1. Argillaceous sand	2

Dr. Cooke identified the following fossils in a collection from this exposure and determined the horizon to be Jacksonian:

List of Fossils from 3 1/2 Miles Southeast of Stony Creek Church

Bryozoa (Rich Hill fauna)[1]
Periarchus pileus-sinensis (Rav.)
Ostrea sp.
Pecten perplanus Morton
Proctocardia sp.
Crassatellites sp.

Near Bond's Store (map locality T-3).—A deep gully on the east side of the public highway, 1¼ miles south of Bond's store, exposes 13 feet of soft, white, highly fossiliferous limestone of Jackson age. The stone is overlain by fullers earth which is in turn overlain by red and mottled residual sands. Cooke identified Bryozoa (Rich Hill horizon), Periarchus sp. and *Pecten perplanus* Morton from this exposure. The residual sands capping the hill is probably residual of beds of late Eocene or Oligocene age.

Fitzpatrick Place (map locality T-6).—Several exposures of the characteristic Jackson limestone of this section occur on the Fitzpatrick place, between Tarversville and Westlake. Bryozoa (Rich Hill fauna), *Periarchus pileus-sinensis* (Rav.) and *Pecten perplanus* Morton were determined by Cooke from a collection obtained from an exposure on Crooked Creek, 3½ miles northeast of Westlake.

[1] Dr. R. S. Bassler has kindly identified the Bryozoa in this and other collections.

Near Danville.—On the east side of the Macon, Dublin & Savannah Railroad, 1½ miles north of Danville, excavating for road bed material has uncovered a bed of *Ostrea georgiana* shells (identified by Cooke) in an arenaceous, calcareous matrix. Casts of other fossils are likewise present but unidentifiable. One mile east of this exposure, at "Kaolin Spring" there is an exposure of bluish fullers earth at an altitude of at least several feet higher than the shell bed.

Bibb County

Near Old Bond P. O. (map locality Bi-1).—Jacksonian limestone is exposed on the Ard place, 1½ miles northeast of the old Bond P. O. The stone outcrops in several gullies and on the gentle slopes of a low knoll. No difference between this material and that of exposures of the Jackson limestone in Twiggs and Houston counties was noted. Bryozoa, Periarchus sp. and *Pecten perplanus* Morton were recognized.

Bleckley County

Near Ainslie Station (map locality B-1).—An excellent exposure of limestone of Jackson age occurs on the east side of Shellstone Creek, 1¼ miles east of Ainslie, on the Weatherly place. The following section is descriptive of the strata exposed:

Section on Weatherly Place, East Side of Shellstone Creek, 1 1/4 Miles East of Ainslie Station

	Feet
Residual Jackson.	
6. Red argillaceous sands to top of escarpment. No sharp line of contact between this and the underlying bed	40
Jackson group.	
5. Cream colored fullers earth (weathered) with some sand	20
4. Hard, pinkish, partly crystalline limestones, Turritella sp.	1
3. Medium hard, white, highly fossiliferous limestone.	5
2. Soft, white, porous, friable, highly fossiliferous limestone	15

Recent.	
1. Creek bottom land	3
0. Creek bed	0

Cooke identified the following fossils from collections made at this exposure:

List of Fossils from 1 1/4 Miles East of Ainslie Station

(See above section)

Upper 1 foot of bed 3

Periarchus sp.
Semele? sp.

Bed No. 2

Bryozoa (Rich Hill fauna)
Periarchus pileus-sinensis (Rav.)?
Pecten perplanus Morton

Lower 1 foot of bed No. 3

Lunulites sp.
Flabellum wailesii Conrad?
Endopachys maclurii (Lea)?
Dentalium sp.
Leda multilineata Conrad
Panope sp.
Crassatellites sp.

Houston County

Small Place (map locality H-6).—An excellent section of the Jackson group strata is exposed on the Geo. L. Small property, 4 miles east of Kathleen, in a gully one-half mile northwest of the Small residence.

Section on Small Place, 4 Miles East of Kathleen

	Feet
Residual Jackson.	
8. Red sands, mottled arenaceous clays and flint	50
Jackson group.	
7. Medium soft, cream colored, highly fossiliferous limestone	15
6. Cream colored fullers earth (weathered)	16
5. Hard, white limestone	2
4. Cream colored, arenaceous fullers earth (weathered). Six layers of hard, white limestone 4 to 6 inches thick	28
3. Mottled clay	2
2. Hard, cream colored, partly crystalline limestone. Fossils	2
1. Soft, white, porous, highly fossiliferous limestone. Fossils in lower 10 feet mainly Bryozoa with	

Periarchus sp. and *Pecten perplanus* Morton. Upper 8 feet has a greater variety................	18
0. Talus to creek bottom..............................	5

List of Fossils from Small Place, 4 Miles East of Kathleen, Bed No. 7 of the above section (Identified by C. Wythe Cooke)

Lunulites sp.
Periarchus sp.
Ostrea georgiana Conrad
Pecten perplanus Morton?
Corbula sp.
Venericardia sp.

Descriptions of other exposures in Houston County are given in place in this report on "Individual Locality Descriptions" and in the report on the "Geology of the Coastal Plain of Georgia" by Veatch and Stephenson, Georgia Geological Survey Bulletin No. 26, 1911.

Dooly County

Carter Place (map locality D-3).—There are several exposures of highly fossiliferous fullers earth and limestone on the J. M. Carter place, 1½ miles southeast of Lilly, on the northwest side of Pennehatchie Creek. From a collection of fossils, mainly Bryozoa, sent to Dr. Cooke, he determined the horizon to be middle Jackson, probably the Rich Hill horizon.

Flint River

The limestone at Bainbridge, Decatur County, formerly referred to the Vicksburg formation, has recently been discovered to be of Ocala (Jackson) age by Cooke,[1] who has also determined from fossils collected by himself and the writer that the limestone exposed along and near the Flint River from near the northern boundary of Crisp County to Bainbridge is also of Jackson age. The data upon which this opinion is based are not yet ready for publication. On the map accompanying this report this and the contiguous territory underlain by this limestone is mapped as "Undifferentiated Eocene and Oligocene."

[1] Cooke, C. W., The age of the Ocala limestone: Prof. Paper, U. S. Geol. Survey, No. 95-I, 1915, p. 110.

UNDIFFERENTIATED EOCENE AND OLIGOCENE

The "Undifferentiated Eocene and Oligocene" of this report includes those portions of the Coastal Plain formerly mapped as the Vicksburg formation. This change is based upon investigations near Albany by Dr. Vaughan[1] and Dr. Cooke's study of the fossils collected by himself and the writer from the limestones along the Flint River between Crisp County and Bainbridge. The limestone from Albany to Bainbridge is correlated by Cooke with the Ocala formation of Florida, the upper division of the Jackson group. The complete data are not yet ready for publication.

These strata outcrop over a large area in the southwestern and north central parts of the Coastal Plain and over small areas along and near the Savannah River, in Burke and Screven counties. In the large area the beds cover parts or all of Laurens, Bleckley, Pulaski, Dodge, Wilcox, Houston, Dooly, Crisp, Sumter, Webster, Lee, Terrell, Randolph, Clay, Calhoun, Dougherty, Mitchell, Baker, Early, Miller, and Decatur counties. The limestone exposures along and west of the Flint River are of Jackson age and the outcrops at and below Hawkinsville on the Ocmulgee River are of Vicksburg age.

The strata of this group lie between the lower part of the Jackson group (Eocene) below and the Chattahoochee formation (Oligocene) above. Southwest of Sumter County the beds overlap the lower limestone of the Jackson and rest unconformably on the Claiborne and Wilcox formations. East of the Flint River deposits of later than the Oligocene overlap these undifferentiated beds.

Limestones, clays, flint, and residual clays and sands make up the beds under consideration. Limestones outcrop along the Ocmulgee and Flint rivers and in several localities west of the latter streams, notably along Kinchafoonee and Fowltown creeks in Lee County and along Spring Creek in Calhoun and Decatur counties. Residual red and mottled sands and sandy clays cover all of the uplands underlain by the limestone beds. Fossiliferous flint is very generally distributed.

[1] Veatch, Otto, and Stephenson, L. W., Geology of the Coastal Plain of Georgia: Bull. Ga. Geol. Survey, No. 26, 1911, pp. 316-317.

There are excellent exposures of huge boulders of this silicified limestone along Spring, Ichawaynochaway, and Chickasawhatchie creeks. Superficial Pleistocene sands cover large areas of the strata along the terrace planes of the larger streams in the area underlain by these undifferentiated strata.

The thickness of these strata was estimated by Veatch[1] to be around 300 feet in the southwestern part of the State and less than 100 feet in Randolph and Webster counties.

The area underlain by these deposits is generally rolling to level. Along a few of the larger streams there are occasional steep escarpments less than 100 feet high. Shallow ponds and depressions due to the solution of the limestone and subsequent caving of the roofs are frequently seen throughout the area but more especially in the southwestern part of the State. These depressions frequently cover a hundred acres or more.

APALACHICOLA GROUP[2]

The Apalachicola group of the Oligocene series in Georgia includes the Chattahoochee and Alum Bluff formations.

CHATTAHOOCHEE FORMATION

The Chattahoochee formation appears at the surface in relatively small areas, being largely concealed by the overlying Alum Bluff and later formations. Good exposures occur along Flint River and in lime sinks near Recovery in Decatur County. Strata belonging to the formation were noted by Langdon[3] on Chattahoochee River, 9 miles above River Junction, Fla. The formation appears at Forest Falls and other lime sinks in the northern part of Grady County, in the vicinity of Metcalf and Thomasville, Thomas County, and in the beds and bluffs of Ochlockonee, Withlacoochee, and Allapaha rivers near the Georgia-Florida line. On Ocmulgee River near Abbeville and near

[1] Veatch, Otto, and Stephenson, L. W., Geology of the Coastal Plain of Georgia: Bull. Ga. Geol. Survey, No. 26, 1911, p. 309.

[2] Abstracted from Geology of the Coastal Plain of Georgia: Bull. Ga. Geol. Survey, No. 26, 1911.

[3] Am. Jour. Sci., 3rd ser., Vol. 38, 1889, p. 324.

Hawkinsville the formation is believed to be represented by fragmentary beds and by residual flint masses containing corals. Limestone, which outcrops near Jacksonboro on Briar Creek in Screven County, has been correlated by Vaughan with the Chattahoochee formation. Limestone, which outcrops in a small area northwest of Millen, Jenkins County, is provisionally considered as a part of the same formation; but the evidence for this classification is admittedly very meager. Limestone of the Chattahoochee formation occurs near Cordele, Crisp County, and probably also 7 miles northwest of Sylvester, 3 miles west of Bridgeboro, and 5 miles northwest of Sale City. Strata of this formation are believed to outcrop in the escarpment east of Flint River from Crisp County to Decatur County but are largely obscured by weathering.

Buried representatives of the formation are believed to underlie nearly all the Coastal Plain of Georgia southeast and south of the areas of outcrop. The formation has been recognized on paleontologic evidence in a well boring at Tarboro, Camden County, between the depths of 375 and 400 feet.

Pumpelly[1] and Vaughan[2] have recognized an erosion unconformity between the Chattahoochee and the underlying limestone in Decatur County. At Blue Springs, on Flint River, 4 miles south of Bainbridge, both formations are present, but the contact between the two is much obscured by weathering of both.

At Red Bluff, 7 miles north of Bainbridge, a contact similar to that at Blue Springs is exposed. The Chattahoochee formation appears as fragments of flint in residual sandy clay, and the weathered limestone of the Jackson group appears at the base of the bluff. There is evidence of an erosion unconformity at this locality, and also at the bluff back of the old factory about 2 miles above Bainbridge.

Sedimentation was probably continuous from the beginning of Chattahoochee to the end of Alum Bluff, for no evidence of an erosion interval separating the two formations has been observed in the

[1] Am. Jour. Sci., 3rd ser., Vol. 46, 1893, pp. 445-447.
[2] Science, new ser., Vol. 12, 1900, pp. 873-875.

field. McCallie,[1] however, has noted an unconformity at the old Toy phosphate pit, 3½ miles west of Boston; but whether this is due to erosion or to solution and irregular weathering of the limestone has not been determined. When this locality was visited by the writer the relations of the clay to the limestone had become obscured by the debris filling the pits.

The Chattahoochee formation is, in general, calcareous and varies from compact, pure, crystalline limestones to earthy argillaceous limestones and calcareous sands and sandstones. Compact, gray, drab, or white fossiliferous limestones make up the bulk of the formation. A brecciated or conglomeratic structure is characteristic of some of the beds, the phenomenon being observed at nearly all localities where there are good exposures. The rock is phosphatic at a number of places, containing brown or black rounded pebbles of phosphate or fragments of bones and teeth. The limestones at the base of the formation have been replaced by silica at several localities and at others are represented by fragmental beds of flint containing corals and other fossils in a matrix of residual clay. The flint closely resembles that of the underlying formation and cannot everywhere be easily distinguished from it.

Northwest of Faceville, Decatur County, the Chattahoochee formation has a probable total thickness of 100 feet. At Forest Falls, or Limesink, in the northern part of Grady County, it has an exposed thickness of 85 or 90 feet. No very reliable data are at hand for estimating its total thickness to the east and northeast, but its maximum probably does not exceed 250 feet.

In portions of Decatur, Grady, Thomas, Brooks, and Lowndes counties, where the Chattahoochee formation lies near the surface, the topography is a little more hilly and rugged than in other parts of southern Georgia. Lime sinks, lakes, and ponds due to the underground solution and consequent caving in of the limestones of the formation are notable features of the topography.

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[1] McCallie, S. W., Phosphates and Marls of Georgia: Bull. Ga. Geol. Survey, No. 5-A, 1896, p. 62.

The formation is tilted slightly southward and southeastward. The dip is low, probably not over 8 feet to the mile. The top of the formation is estimated to be about 225 feet above sea level at Forest Falls or Limesink, and about 200 feet above sea level near Faceville, approximately 24 miles to the southwest. At Red Bluff, 7 miles north of Bainbridge on Flint River, where Vaughan has determined paleontologically the presence of the Chattahoochee, its base can hardly be more than 20 feet above the river, and at Blue Spring, 4 miles below Bainbridge, is about 10 feet above the river. This indicates a very low dip.

Local dislocations of beds, due to underground solution and consequent sinking, have been observed in Thomas and Decatur counties.

ALUM BLUFF FORMATION

The Alum Bluff formation outcrops in southern and south-central Georgia throughout a large area extending from Decatur County northeastward to Savannah River. The limit of the deposits of the Alum Bluff is on the north approximately Waynesboro, Tennille, and Vienna; on the west the west-facing escarpment which separates the Altamaha upland from the Flint River valley; and on the east a line extending from Savannah River near the mouth of Buck Creek through Sylvania, Reidsville, and Blackshear to the western edge of Okefenokee Swamp.

Except along stream, escarpments near streams, and near the Florida line, the entire area underlain by the Alum Bluff formation is mapped as "Undifferentiated Oligocene to Pleistocene, inclusive."

The Alum Bluff formation conformably overlies the Chattahoochee formation. On Savannah and Altamaha rivers it is separated from the overlying Miocene by an erosion unconformity probably of minor importance. Throughout the greater part of the area underlain by the Alum Bluff formation its weathered products are believed to form the surface material, but in southeastern Georgia it is overlain by lithologically similar undifferentiated deposits, ranging in age from Miocene to Pleistocene. In narrow areas along all the larger streams the formation is overlain by thin terrace deposits of Pleistocene age.

The Alum Bluff appears in a number of different lithologic phases, including subordinate beds of pebbles, coarse angular sands, coarse grained, aluminous sandstones or grits, sandy clays, fullers earths, phosphatic sands, quartzites, sandstones, silicified clays, and limestones or calcareous layers and nodules of local extent. Greenish or gray argillaceous sands and sandy laminated clays form the greater part of the formation.

The thickness of the Alum Bluff formation in Georgia is estimated to be 70 to 200 feet. At no known locality can the full thickness of the formation be seen in natural exposure, and the estimate is based chiefly on well records.

The higher divides and uplands underlain by the Alum Bluff and mapped as "Undifferentiated Oligocene to Pleistocene, inclusive," present a peculiar topography. Part of this area constitutes the Altamaha upland, one of the major topographic divisions of the Coastal Plain of Georgia, an area of low hills with gentle slopes and softened outlines, of shallow saucer-shaped valleys, many of which are not more than 40 or 50 feet deep, of sluggish clear-water streams bordered by swamps and sand hammocks and of "bays" and cypress ponds. Altamaha and Oconee rivers have cut deep valleys, and the precipitous bluffs along their courses form an exception to the general type of topography of the area.

The formation has a very low southward and southeastward dip, certainly much less than that of the older Eocene formations. On Savannah River the dip does not exceed 4 or 5 feet to the mile, and near the Florida line the beds must be almost horizontal, for the streams have cut through them, exposing the underlying formations. No evidence of broad flexures nor even minor folding and faulting was observed in the natural exposures of the strata. However, the probability that a broad arch exists in the southern part of the State has been mentioned.

UNDIFFERENTIATED OLIGOCENE TO PLEISTOCENE, INCLUSIVE[1]

The materials designated "Undifferentiated Oligocene to Pleistocene, inclusive," on the geologic map have been partly discussed under Alum Bluff formation, and under Miocene series.

The bulk of the deposits previously included by Stephenson and Veatch, and by others in the Altamaha formation and referred questionably to the Pliocene are now regarded by them as Oligocene and as probably contemporaneous with part of the Alum Bluff formation. This material consists of irregularly bedded, locally indurated sands, clays, and gravels. On the whole the individual beds are homogeneous, but locally they are a heterogeneous mixture. The indurated sands and the conglomerates contain a peculiar greenish or greenish-gray disseminated clay and are described as "gray or greenish aluminous grits." The pebbles are predominantly subangular, many of them lath shaped, and the sands are universally harsh or in sharp angular grains. Feldspar is present in great abundance, both as pebbles and as semi-decomposed disseminated grains, and phases of the deposits may be appropriately described as "feldspathic grit." Calcareous phases are totally absent. The weathered surface materials are mottled and splotched in red, yellow, purple, and gray, the surface aspects differing in this respect from those of any other formation of the Coastal Plain. These striking effects are probably due to unequal weathering, oxidation, and unequal distribution of iron material. This peculiar surface phase is not a later deposition, but results from weathering, although in many places it appears to overlie unaltered beds unconformably. The materials are very coarse grained, even at points 100 miles from their northern margin. The beds that have been locally indurated to sandstones, conglomerates, and claystones, do not differ essentially in composition from the non-indurated materials.

The age of most of this material west of a line from Rocky Ford to Waycross is believed to be Upper Oligocene. East of that line it probably ranges in age from Miocene to Pleistocene.

[1] Abstracted from Water Supply Paper, No. 341, U. S. Geol. Survey.

MIOCENE SERIES[1]

MARKS HEAD MARL

The Marks Head marl has been differentiated at and in the vicinity of Porters Landing, Savannah River, Effingham County, and is doubtless represented in the undifferentiated Miocene in the sections above Porters Landing, at least as far as Hudsons Ferry, and in the sections between Porters Landing and Sisters Ferry.

The formation is almost entirely concealed by younger sediments outcropping only in the bluffs of streams. For this reason it has had little or no influence on either the topography or the soil of the region. So far as can be determined from natural exposures, it lies almost horizontal, having only a very slight dip southward, probably not more than 4 feet to the mile.

The Marks Head marl rests upon the Alum Bluff formation of the Oligocene, from which, according to exposures on Savannah River, it is separated by an erosion unconformity. The formation is overlain unconformably by the Duplin marl, and as the Marks Head marl is early Miocene and the Duplin marl late Miocene the unconformity separating them is important.

The beds of the formation consist of gray or brownish compact argillaceous sands containing large calcareous nodules and, in places, of friable phosphatic sands containing shells. The phosphatic sands consist mainly of quartz grains with subordinate percentages of phosphate in the form of small, brown and black, smooth or water-worn particles of bones and teeth, disseminated clay, and calcium carbonate in the form of shells and calcareous nodules. A maximum observed thickness of 45 feet occurs in some of the sections in the vicinity of Porters Landing on Savannah River.

DUPLIN MARL

The Duplin marl has been differentiated in the sections at Porters Landing and at Mount Pleasant Landing, 1½ miles below Por-

[1] Abstracted from Veatch and Stephenson's report on the Geology of the Coastal Plain of Georgia: Bull. Ga. Geol. Survey, No. 26, 1911.

ters Landing. The formation is doubtless represented in undifferentiated Miocene beds recognized in bluffs above Porters Landing as far as Hudsons Ferry, and below Porters Landing perhaps as far as Purisburg, S. C., 23 miles above Savannah. The formation has also been differentiated at Doctortown, at Buzzards Roost Bluff, and at Bugs Bluff on Altamaha River. The terrane probably underlies superficial formations throughout much of the region intervening between its exposures on Altamaha and Savannah rivers.

The Duplin strata dip southeastward at a low angle, probably not greater than 3 or 4 feet to the mile. Except in a few stream bluffs the formation is probably concealed over the entire area of its occurrence by superficial deposits, and for this reason has had little or no part in determining the topographic features of the character of the soils.

The Duplin marl rests unconformably upon the Marks Head marl, or, where the latter is absent, upon the Alum Bluff formation of the Oligocene. The former relations were observed in sections examined at and in the vicinity of Porters Landing, Savannah River, and the latter relations are believed to obtain in sections on Altamaha River, at the bluff at Doctortown, at Buzzards Roost Bluff, and at Bugs Bluff.

In the vicinity of Porters Landing the formation is overlain by terrace deposits of Pleistocene age.

The formation as exposed on Savannah River is mainly a shell marl, consisting of shells in a matrix of coarse phosphatic sand, but in places is a fine gray or brown quartz sand containing scarcely any fossils or calcareous matter. On Savannah River it probably does not reach a thickness of more than 10 to 12 feet.

On Altamaha River the Duplin marl consists of 12 or 15 feet of friable, sandy, and pebbly shell marls, and bluish, compact, fine grained, argillaceous, fossiliferous sands. It overlies, unconformably, strata of probable Alum Bluff age and is in turn overlain by undifferentiated, vari-colored sands and clays which probably belong, in part, to the Pliocene and, in part, to the Pleistocene.

A. *OSTREA GEORGIANA* BED AT SHELL BLUFF, SAVANNAH RIVER, BURKE COUNTY.

B. EXPOSURE OF LIMESTONE OF THE JACKSON FORMATION IN A GULLY AT RICH HILL, FIVE MILES SOUTHEAST OF ROBERTA, CRAWFORD COUNTY.

PLIOCENE SERIES[1]

Although the existence of strata of Pliocene age in Georgia has not been definitely proved, certain deposits have been referred with greater or lesser degree of confidence to this epoch. The deposits of the Atlantic and Gulf Coastal Plain to which the name Lafayette formation has been applied have for many years been regarded as of probable Pliocene age. The Lafayette formation is represented by McGee as covering the entire Coastal Plain of Georgia, and has been described by different investigators from numerous localities in Georgia. Recent investigations have shown, however, that many and perhaps all of these correlations were erroneous.

Certain fossiliferous strata exposed on Satilla and St. Marys rivers have, on paleontologic evidence, been considered as probably of Pliocene age and are described under the name Charlton formation. These marine strata probably have littoral shallow-water representatives in the undifferentiated Oligocene to Pleistocene deposits to the north in Ware, Pierce, Appling, and Wayne counties.

CHARLTON FORMATION

The name Charlton is derived from Charlton County, Ga., and is applied to an argillaceous limestone and clay formation exposed in the banks and bluffs of St. Marys River from Stokes Ferry, 11 miles south of St. George, Charlton County, to Orange Bluff, near Kings Ferry, Fla. From a study of the fossil collections from the St. Marys localities T. W. Vaughan has classified the formation as probably Pliocene.

Fossiliferous marls probably referable to the formation have been observed on Satilla River at Burnt Fort, 12 miles northeast of Folkston, Charlton County; on land of W. M. Thrift, 6 miles east of Winokur, Charlton County; and at the King plantation, 6 miles south of Atkinson, Wayne County. Fossils from the last-named locality have

[1] Abstracted from Veatch and Stephenson's report on the Geology of the Coastal Plain of Georgia: Bull. Ga. Geol. Survey, No. 26, 1911.

been referred by Aldrich[1] and Dall[2] to the Pliocene. General considerations based on structure and on the lithologic character of the materials seem to justify the reference of this marl bed to the Charlton formation.

The relations of the Charlton formation to the Miocene are not definitely known. From Stokes Ferry, where the top of the formation is perhaps 30 or 35 feet above sea level, the upper non-conformable surface descends gradually down-stream and finally reaches tide level. According to the geologic map of Florida, by Matson and Clapp,[3] the Jacksonville formation (Miocene) outcrops at elevations of 50 to 100 feet above sea level a short distance south and east of St. Marys River. Beds from which T. W. Vaughan has identified Miocene fossils, are exposed at low tide at Owens Ferry, Satilla River, Camden County. In view of these occurrences of Miocene the Pliocene beds on St. Marys River, if correctly correlated, may occupy an erosion basin in Miocene strata, or, if the latter are absent beneath them, they may rest in a similar basin in pre-Miocene strata probably referable to the Alum Bluff formation (Oligocene). The great thickness attributed to the Miocene at Jacksonville, 460 feet, and the fact that the Miocene there is supposed to lie unconformably upon the Vicksburg makes the former alternative seem the more probable. There are no data for estimating the thickness of the formation, for only 12 or 15 feet of strata have been observed in natural exposures.

QUATERNARY SYSTEM[4]

PLEISTOCENE SERIES

The Pleistocene deposits consist of thin accumulations of sand, clay, and gravel on terraces of fluviatile and marine origin. The only systematic description of the Pleistocene of the Coastal Plain

[1] Nautilus, Vol. 24, No. 11, 1911, p. 131.
[2] U. S. Nat. Mus. Proc., Vol. 46, 1913, pp. 226, 227.
[3] Florida Geology Survey, Second Annual Report, 1909.
[4] Abstracted from Geology of the Coastal Plain of Georgia: Bull. Ga. Geol. Survey, No. 26, 1911.

of Georgia previously given is that of McGee[1]. McGee first studied the Pleistocene in the District of Columbia, gave it the name Columbia formation, and differentiated it into three phases, the fluvial, interfluvial, and low-level phases, all of which he recognized in Georgia.

The classification given in the present report is based largely on topography, and the formations are here described in greater detail than in McGee's report. The name Columbia as a group term is retained. The divisions are as follows:

Satilla formation.	Okefenokee formation.
Marine terrace deposits.	Coastal terrace sand.
Fluviatile deposits.	Fluviatile deposits.

The solution of the Pleistocene problems of Georgia, and in fact those of the Atlantic Coast region in general, depends largely on a knowledge of topographic details, which cannot be available until detailed topographic maps are made.

In Georgia the Pleistocene formations are not superimposed one upon the other, but occupy terraces at different topographic levels.

During the Okefenokee epoch 2 to 15 feet of gray sands and other sediments were laid down on a terrace plain of probable marine origin, now 60 to 125 feet above sea level, and contemporaneous fluviatile deposits of gravel, sand, and loam, having a maximum thickness of 50 feet, were laid down on the "second" terrace skirting the larger rivers.

During the Satilla epoch gray sands and muds a few to 50 feet in thickness were laid down on a marine terrace, a flat plain 20 to 40 miles broad, bordering the coast at elevations of 15 to 40 feet above sea level, and corresponding terrace alluvium was deposited along the rivers.

Although the available data are too incomplete to permit positive statements, it is not improbable that an older Pleistocene terrace plain exists west of and at a higher elevation than the Okefenokee terrace. Evidence of such a plain is to be seen in the topographic

[1] McGee, W. J., The Lafayette formation: U. S. Geol. Survey, 12th Ann. Rept., Pt. 1, 1891, pp. 384-407.

aspect of the country along the Atlantic Coast Line Railroad between Valdosta, Lowndes County, and Waycross, Ware County; along the Atlantic Coast Line Railroad between Pearson, Coffee County, and Waycross; and along the Southern Railway between Baxley, in Appling County, to near Jesup, Wayne County. The general surface of the belt of country crossed by these railroads is a nearly level plain which gradually descends toward the coast. Along the first mentioned railroad there is a descent from an elevation of 215 feet at Valdosta to 140 feet at Waycross; along the second there is a descent from 205 feet at Pearson to 140 feet at Waycross; and along the third a descent from 206 feet at Baxley to 155 feet at Odum.

The northern part of Effingham and the southern parts of Screven and Bulloch counties also present the aspect of a plain similar to the Okefenokee plain.

RECENT SERIES

The Recent deposits, or those formed since the close of the Pleistocene or the uplift of the Satilla or latest Pleistocene terrace and now in the process of formation, consist of (1) marsh and tide-swamp muds, (2) beach and dune sands, (3) river flood-plain deposits, (4) inter-stream swamp deposits, and (5) certain terrigenous deposits, semi-alluvial in character.

The processes by which the Satilla terrace, with its accompanying deposits, was formed are being repeated at the present time along the coast. The Recent terrace thus being formed is largely submarine. Beach sands are being laid down on the ocean front, sands and clays are being deposited in the estuaries, and muds are being deposited in the marsh and tide-swamp lands. Though observations have not been made at many localities, it may be said that the thickness of the Recent deposits in the area inundated by the tides probably does not exceed 6 feet. The composition of the muds is indicated by the following analysis of a sample from St. Simons Island, collected by

S. W. McCallie and analyzed by Edgar Everhart:

Analysis of Mud from St. Simons Island

Moisture at 100° C.	4.62
Loss on ignition	9.94
Soda (Na_2O)	3.06
Potash (K_2O)	1.13
Lime (CaO)	.40
Magnesia (MgO)	1.28
Alumina (Al_2O_3)	13.67
Ferric oxide (Fe_2O_3)	4.86
Titanium dioxide (TiO_2)	1.01
Sulphur trioxide (SO_3)	.24
Phosphorus pentoxide (P_2O_5)	.22
Chlorine (Cl)	1.77
Silica (SiO_2)	57.95
Total	100.15

In places the Satilla terrace is separated from the Recent terrace by bluffs 10 to 15 feet high, and at other localities the two merge into each other.

In the southeastern part of the Coastal Plain of Georgia are numerous swamps ranging in size from a single acre to the immense tract known as Okefenokee Swamp. Peaty accumulations or decayed plant matter with more or less silt and sand are being formed in these swamps. In the Okefenokee Swamp accumulations of peat 4 to 8 feet thick have been observed. Some of the swamp areas are densely wooded and have been the roosting places of birds for perhaps centuries, and a phosphatic muck is being slowly formed from their dung and dead bodies.

SUPERFICIAL GRAY SANDS OF THE UPLAND

Superficial grayish or brownish, incoherent quartz sands a few inches to 30 feet thick cover large portions of the inter-stream uplands of the Coastal Plain of Georgia at elevations higher than the Pleistocene terrace plains. Because of the sterility of the soils which these sands produce and their influence on the topography and tree growth, they attract the attention even of those not interested in geology. The sands are not everywhere of the same origin. Much of the sand is residual and cannot be referred to any one geologic period or formation. However, in places there are wind-blown accumulations, and at long intervals marks of stratification can be detected. In this report no attempt has been made to subdivide or to map these sands; a part of such mapping, indeed, would fall within the province of a soil survey.

GENERAL DISCUSSION OF LIMESTONE

CLASSIFICATION OF ROCKS

The crust of the earth is made up of three different classes of rocks—igneous, metamorphic, and sedimentary. Igneous rocks include granite, diorite, trap rock and numerous others, solidified from the molten state at or beneath the surface. A metamorphic rock is one in which the texture and mineral composition of the original rock, either igneous or sedimentary, has been altered by pressure, chemical agencies, heat or combinations of these agencies. Schist, gneiss, and marble (crystalline limestone) are representative of this group. Sedimentary rocks are those which have been deposited on land or in the water by either mechanical, chemical or organic agencies. Samples of this class of rocks are sandstones, shales and limestones.

ORIGIN OF LIMESTONE

Practically all igneous rocks and most metamorphic and sedimentary rocks contain calcium in combination with other elements. The calcium mineral is usually insoluble, or nearly so, but the continued action of weathering agents and the addition of acids to the water allow a very small percentage to be held in solution as the sulphate, carbonate or other salts of calcium.

One liter of pure water at a temperature of 8.7° C. will dissolve 0.01 gram of calcium carbonate ($CaCO_3$).[1] When this water at 15° C. is saturated with carbon dioxide the solubility of the carbonate is increased to 0.385 gram per liter.[2] Meteoric waters falling through

[1] Seidel, Atherton, Solubilities of inorganic and organic substances, 1907, p. 86. D. Van Nostrand Co., New York.

[2] Idem., p. 87.

the air and sinking through the soil absorb small quantities of carbon dioxide which increases their power of taking up calcium carbonate in proportion to the amount of the acid gas (carbon dioxide) held. When this water percolates through the soil and rocks the acid acts on the calcium carbonate encountered, changing it to calcium bicarbonate ($CaH_2(CO_3)_2$), the condition in which the limestone is practically always held in solution in natural waters. These waters finally find their way to the ocean where the deposition of the compounds take place when the conditions are favorable.

This deposition may take place in several ways—through the action of organisms, precipitation from evaporating waters, and precipitation through the action of other chemical compounds. The greater portion of the limestone deposits was probably formed by the secretions or shells of living organisms such as foraminifera, corals, mollusks, etc. Dr. T. Wayland Vaughan states that "In the shoal waters of southern Florida and the Bahamas, bacteria are the most important agency whereby calcium carbonate is taken from the sea-water."[1] Before the shell of the sea animals reaches its final position in the bed of limestone being formed, it was frequently so highly comminuted by the action of the waves that no trace of the original form of the shell was left. Again the animals lived and left their shells in still waters forming beds made up largely or entirely of well-preserved fossils. An excellent example of this is the highly fossiliferous limestone bed in the Jackson formation of the Coastal Plain of Georgia.

When a body of water containing calcium carbonate in solution is evaporated down to such a volume that it can no longer hold all of the compound in solution, the calcium carbonate will be precipitated, thus forming a bed of limestone. This is well illustrated in certain inland salt water seas or lakes that have no outlet. Other deposits of limestone similar to these are formed when the calcium carbonate

[1] Vaughan, T. Wayland, answer to discussion of: Coral reefs and reef corals of the southeastern United States, their geologic history and significance: Bull. Geol. Soc. of Am., Vol. 26, No. 1, March, 1915.

in water comes into contact with other compounds which will cause its precipitation.

Limestones frequently contain varying proportions of magnesium carbonate. A stone containing 54.35 per cent calcium carbonate and 45.65 per cent magnesium carbonate is true dolomite.[1] In common usage, however, a stone containing from 20 to 25 per cent of magnesium carbonate is known as dolomite. Below this percentage it is known as magnesian limestone. These dolomitic limestones are believed to have been formed by the replacement of a part of the calcium carbonate by magnesium carbonate either before or after the bed emerged from the water.

VARIETIES OF LIMESTONE[2]

The varieties of limestone are based on their physical character or texture and their chemical compositions. The following varieties are common to the Coastal Plain of Georgia:

Classification according to texture:

1. Compact, dense, fine grained to granular limestone.
2. Partly crystalline to crystalline limestone.
3. Fossiliferous limestone.
4. Chalky or ''rotten'' limestone.
5. Oölitic and pisolitic limestone.
6. Brecciated limestone.
7. Sandy or arenaceous limestone.
8. Marl.

Classification according to chemical composition:

1. High-calcium limestone.
2. Magnesian limestone.
3. Dolomite.
4. Argillaceous limestone.
5. Siliceous limestone.

Under both of these classifications the varieties grade into each other to such an extent that the characteristics of two varieties are frequently present in one piece of stone.

[1] Dana, E. S., A text book of mineralogy, p. 358, John Wiley & Sons, New York, 1910.

[2] A modification of the classification scheme used by Burchard, E. F., The Source of Lime: Mineral Resources U. S. for 1913, U. S. Geol. Survey, 1914, Pt. 2, p. 1515.

CLASSIFICATION ACCORDING TO TEXTURE

Compact, Dense, Fine Grained to Granular Limestone.—This type of limestone is not very extensively distributed over the Coastal Plain of Georgia in deposits of sufficient extent to be worked alone, but it does occur in thin strata and in a few thick beds along the west of the Flint River. It is well adapted to the manufacture of lime when of sufficient purity, while the harder and tougher varieties can be used for road metal, concrete aggregate and railroad ballast. Its value for agricultural uses depends upon its composition, which is usually comparatively low in impurities.

Partly Crystalline to Crystalline Limestone.—In the majority of cases this variety of stone was probably originally a dense, compact stone that has been re-crystallized by the action of water and in some cases, also, pressure. This stone is rather extensively distributed over the limestone regions of the southern part of the State but always in thin beds. It is suitable for those uses mentioned in the previous paragraph.

Fossiliferous Limestone.—This is rather an indefinite term and may mean a stone containing an occasional fossil or one made up entirely of fossils. In this report the term, when used to describe the appearance of the stone, indicates that it is made up largely or entirely of fossils. This variety of limestone makes up practically all of the Jackson limestone beds of Georgia exposed in the section between the Oconee and the Flint rivers. The stone is of good quality, chemically, but its softness eliminates it from uses where strength and wearing qualities are essential.

Chalky or "Rotten" Limestone.—The chalky limestone of the Coastal Plain of Georgia is a soft, white, fine grained limestone frequently containing some clayey material. The purer beds are usually inter-bedded with a hard, compact stone and are exposed along the Flint River while the impure variety occurs as a massive bed on the Ocmulgee River in the vicinity of Hawkinsville. This stone, because of its softness, is only suited for agricultural purposes except in a few places where the composition is such that it will make a hydraulic lime.

Oölitic and Pisolitic Limestones.—These types of limestones are formed generally in shallow waters where the volume of the water has been evaporated down to such an extent that it is no longer capable of holding the calcium carbonate in solution. The limestone will then precipitate out and if there are present sand grains, clay particles, or, according to some authorities, gas bubbles, the carbonate will gather around these particles to form oölites, or, if larger than a pin head, pisolites. These two types of stone make up a thick, massive bed at the base of the Chattahoochee formation along the southern border of the State. This stone is of exceptional purity and is therefore well suited for those uses which require a high grade of limestone. The stone is hard but not of sufficient toughness to make a first-class road metal or railroad ballast.

Brecciated Limestone is made up of an aggregate of angular limestone fragments in a matrix of softer limestone. The only occurrence of this type of stone is in a thin bed in the upper part of the Chattahoochee formation, along the southern border of the State. Its value depends upon its composition and strength.

Sandy or Arenaceous Limestone is one that was deposited near shore or where the current was strong enough to carry sand in suspension to the point where the calcium carbonate was being deposited. This stone is distributed throughout the Coastal Plain limestone regions. Its value depends upon its composition, hardness, and toughness.

Marl is a term that is frequently misused by others than geologists to indicate various types of clay and comparatively pure limestones, as well as true marls. The term has no definite meaning other than a calcareous material containing high percentages of sand or clay or both. The proportions may vary to a point where it would be preferable to call the material a sandy or argillaceous limestone or in the other direction a calcareous sand or clay. The calcium carbonate content may be, and frequently is, due to fossils. Marls are distributed throughout the limestone sections of south Georgia. Their principal value is for local agricultural uses.

CLASSIFICATION ACCORDING TO COMPOSITION

High-calcium Limestone.—Limestones which contain little or no magnesium carbonate and only a small percentage of impurities are known as high-calcium limestones. Upon being burned they make a lime which will give off a great deal of heat when slaked with water —hot lime. This type of stone is used very extensively in industrial chemical works where magnesium is detrimental to the object in view. It is also valuable for agricultural purposes.

Magnesian Limestones contain varying percentages of magnesium carbonate up to the theoretical percentage of dolomite. These limestones are used for the manufacture of lime, in industrial chemical works, and as a soil corrective.

Dolomite is the double carbonate of calcium and magnesium containing 54.35 per cent calcium carbonate and 45.65 per cent magnesium carbonate, when pure. In common usage any high-magnesian limestone is called dolomite.

Argillaceous Limestone is one containing a relatively large percentage of clayey matter but not sufficient to be called a marl. It is formed in still waters where the current from the land streams is strong enough to bring the clay particles in suspension and then deposit them when the still water is reached. This stone is suitable for local agricultural uses when the carbonate content is not too low and for the manufacture of hydraulic limes and cements.

Arenaceous or Siliceous Limestones are those which contain silica in one or more of its several forms. The silica may be present as spicules of sponges or from other organic sources, as sand grains or finely divided siliceous material. The first mentioned stone is formed similarly to other fossiliferous stones while those containing sand grains were deposited near shore. The last mentioned are formed under the same conditions as argillaceous limestones.

PART II.

DETAILED DESCRIPTION OF CALCAREOUS DEPOSITS BY COUNTIES

LIMESTONE AND MARL

BURKE COUNTY

Practically the whole of the upland of Burke County is covered by red and mottled argillaceous sands, while limestones and marls are exposed along the Savannah River and its larger tributaries. In the report on the Geology of the Coastal Plain of Georgia by Veatch and Stephenson, these deposits are correlated with the Claiborne group; in this report they are classed as undifferentiated Upper Eocene.

The topography is rolling over the greater portion of the county, with steep, comparatively high hills along the principal streams.

W. L. Morris Place (map locality Bu-1).—An exposure of greenish, glauconitic, fossiliferous, arenaceous marl occurs in the bed of McBean Creek on the W. L. Morris place, 5 miles south of Elwood, overlain by several feet of unconsolidated yellow sand. This exposure is at the base of an escarpment which has a 40 per cent slope and reaches an elevation of 40 feet above the creek bed. A sample of the marl shows the following chemical analysis:[1]

Analysis of Marl Sample from W. L. Morris Place, McBean Creek (Sample No. 113)

Soda (Na_2O)	.16
Potash (K_2O)	.12
Lime (CaO)	40.84
Magnesia (MgO)	.46
Alumina (Al_2O_3) / Ferric oxide (Fe_2O_3)	4.06
Phosphorus pentoxide (P_2O_5)	.30
Silica (SiO_2) and insoluble	16.12
Undetermined	37.94
Total	100.00

[1] All analyses in this report were made by Dr. Edgar Everhart, unless otherwise stated.

Calcium carbonate ($CaCO_3$)	73.04
Magnesium carbonate ($MgCO_3$)	.96
Total carbonates	74.00

The position of this deposit beneath the bed of the creek, is such that it could not be worked profitably even though the stone was of much higher grade, except where a small quantity of the material is desired for local agricultural uses.

E. C. Lanier Place (map locality Bu-2).—There are several exposures of limestone on a low ridge or terrace which extends northward from the foot of the steep escarpment on the south side of McBean Creek. The deposit is on the property of E. C. Lanier, 3 miles up McBean Creek from the Central of Georgia railroad tressel. Years ago this stone was quarried, burned and used for building purposes. The old kiln built of the limestone is still intact. The pits show the only exposures of the stone at the present time.

The limestone is medium hard, cream colored and arenaceous. It contains numerous species of very poorly preserved fossils. A sample shows the following analysis:

Analysis of Sample from E. C. Lanier Place, Burke County
(Sample No. 110)

Soda (Na_2O)	.20
Potash (K_2O)	.21
Lime (CaO)	43.02
Magnesia (MgO)	.42
Alumina (Al_2O_3) Ferric oxide (Fe_2O_3)	1.78
Phosphorus pentoxide (P_2O_5)	.25
Silica (SiO_2) and insoluble	10.53
Undetermined	43.59
Total	100.00
Calcium carbonate ($CaCO_3$)	76.90
Magnesium carbonate ($MgCO_3$)	.90
Total carbonates	77.80

This deposit occurs in a low ridge about 300 feet long and 200 feet wide, slightly more than an acre. It has a height of 12 feet with limestone exposed from 3 feet above the bottom land to the surface of the ridge. The overburden is only a few inches. It is probable that prospecting would prove up the limestone in similar and larger terraces which occur along the base of the main creek escarpment.

The low carbonate content, the distance from means of transportation, and the apparent small quantity of stone, seriously interferes with the deposits from becoming of commercial importance. It is, however, a valuable stone for local agricultural uses.

Newton Palmer Place (map locality Bu-3).—Exposures of limestone occur in the escarpment along the south side of McBean Creek just west of the Central of Georgia Railway on the Newton Palmer property. A complete section of the different strata could not be seen, but the following seems to be fairly representative:

Section on Newton Palmer Property, McBean Creek, West Side of Central of Georgia Railway, Burke County

	Feet
6. Concealed, sandy soil on top of hill	34
5. Soft, white, argillaceous, ''rotten'' limestone	7
4. Medium hard, highly fossiliferous limestone; fossils poorly preserved	2
3. Soft, ''rotten'' to consolidated, cream colored, argillaceous limestone	45
Swamp level.	
2. Blue, glauconitic, fullers earth-like clay	6
1. Hard, arenaceous, fossiliferous limestone	2
0. Creek bed	0
	96

Samples for analyses show the following chemical composition:

Analyses of Limestone Samples from Newton Palmer Property

Sample No.	107	108
Soda (Na_2O)	.17	.15
Potash (K_2O)	.17	.02
Lime (CaO)	45.62	47.52
Magnesia (MgO)	1.66	.28
Alumina (Al_2O_3) / Ferric oxide (Fe_2O_3)	.38	1.44
Phosphorus pentoxide (P_2O_5)	.04	.04
Silica (SiO_2) and insoluble	14.35	12.41
Undetermined	37.61	38.14
Total	100.00	100.00
Calcium carbonate ($CaCO_3$)	81.50	84.92
Magnesium carbonate ($MgCO_3$)	.80	.58
Total carbonates	82.30	85.50

Sample No. 107 was taken from beds 5 and 6 of the section. Sample No. 108 was taken from the lower 20 feet of bed 3. More general samples could not be secured, due to the incompleteness and weathered condition of most of the exposures.

This deposit probably belongs to the upper portion of the Claiborne group. The dip of the strata could not be determined, but they are apparently practically level, or dip slightly to the southeast.

These exposures extend along the lower half of this high escarpment for a distance of nearly one-half mile, beginning 200 yards west of the railroad and extending westward. An average profile of the escarpment for this distance shows a 50 per cent slope with the limestone occurring from the base to 54 feet above. There is from 1 to 2 feet of soil and humus over the limestone under the slope. Taking the figures given in this paragraph into consideration there is in the escarpment a body of limestone under a 1- to 2-foot overburden which has a triangular cross section with the vertical side 54 feet high and the base 110 feet long. This body is near one-half mile in length.

These dimensions are merely estimates and are only intended to give an idea of the probable workable extent of the limestone deposit. Natural drainage would be retained within the lower limit given.

The chemical analyses show rather low-grade limestones which, however, are well adapted to agricultural uses. The railroad being within 200 yards of the deposit increases its value to a great extent. However, the comparative low grade of the stone will prevent its being shipped great distances, due to the inert material upon which freight charges must be paid.

As mentioned in the above sectional description of the limestone it is very soft. The rotten stone can be excavated with a shovel, while the harder material can be dug with a pick. This will eliminate the cost of drilling and blasting and preliminary crushing and greatly increase the capacity of the pulverizer. In fact, the softer material which makes up a large percentage of the surface of the stone at least, is in such a state of fineness that it may be applied to the soil without being further pulverized.

Evans-Miller Place (map locality Bu-4).—An exposure of soft, rotten, argillaceous limestone overlying medium soft, white, fossiliferous limestone occurs on the Evans-Miller property, on the south side of McBean Creek, three-fourths mile up-stream from the Augusta-Savannah highway. The soft, rotten strata are exposed in a vertical space for 14 feet while 3 feet of the fossiliferous stone underlies it. Red argillaceous sand immediately overlies the limestone for 12 feet, while the face of the escarpment is covered with soil from this point to the top, a height of 45 feet.

A. LIMESTONE EXPOSURE ON G. S. & F. R. R., SOUTH OF TIVOLA, HOUSTON COUNTY.

B. OLD LIMESTONE QUARRY ON G. S. & F. RIGHT-OF-WAY, SOUTH OF TIVOLA, HOUSTON COUNTY.

Samples of the limestone of the two strata show the following chemical composition:

Analyses of Samples from the Evans-Miller Place, Burke County

Sample No.	111	112
Soda (Na_2O)	.19	.04
Potash (K_2O)	.17	.18
Lime (CaO)	47.12	39.02
Magnesia (MgO)	.46	.44
Alumina (Al_2O_3) / Ferric oxide (Fe_2O_3)	1.78	2.20
Phosphorus pentoxide (P_2O_5)	.12	1.84
Silica (SiO_2) and insoluble	11.73	25.29
Undetermined	38.43	30.99
Total	100.00	100.00
Calcium carbonate ($CaCO_3$)	84.20	69.62
Magnesium carbonate ($MgCO_3$)	1.00	.90
Total carbonates	85.20	70.52

Sample No. 111 is from lower and sample No. 112 from upper limestone bed.

This deposit is a continuation of that on the Palmer place, 2 miles west, (see the above locality description) which is probably of Claiborne age.

This exposure occurs at the base of a practically vertical escarpment and on account of the heavy overburden is not economically workable. Up- and down-stream from this deposit the escarpment slope is gentle and it is quite probable that there are workable deposits contained therein. The impure quality of the upper bed is such that the deposit is of little or no commercial value, however, the stone is so easily worked that it could be used very profitably for local agricultural purposes. The soft stone in its rotten condition can be readily worked with a shovel and is so finely divided that it should give excellent results without being further pulverized.

M. H. Ushur Property (map locality Bu-4).—Small exposures of this rotten arenaceous limestone occur on the M. H. Ushur place along the River road on the south side of McBean Creek, one-half mile east of McBean Station. These outcrops are in small washes and road cuts at the foot of a steep escarpment. The immediate overburden of the limestone is 1 to 3 feet of soil and humus.

The deposit is of little commercial value, except locally, due to the comparative small quantities under light overburden and the distance from means of transportation. The rotten stone is in such a state of pulverization that it can be worked and applied to the soil without grinding.

James Mobley Property (map locality Bu-5).—A 6-foot exposure of soft, arenaceous, fossiliferous limestone occurs on the James Mobley place, 2½ miles east of Shell Bluff post office and one-half mile east of the old Mobley residence. A sample of the material shows the following analysis:

Analysis of Sample from James Mobley Place

(Sample No. 109)

Soda (Na_2O)	.13
Potash (K_2O)	.16
Lime (CaO)	41.72
Magnesia (MgO)	.27
Alumina (Al_2O_3) / Ferric oxide (Fe_2O_3)	2.02
Phosphorus pentoxide (P_2O_5)	.06
Silica (SiO_2) and insoluble	21.38
Undetermined	34.26
Total	100.00
Calcium carbonate ($CaCO_3$)	74.40
Magnesium carbonate ($MgCO_3$)	.60
Total carbonates	75.00

The material is lithologically similar to the rotten limestone along McBean Creek and is probably at the same horizon, in the Claiborne group.

The exposure is in the face of a long excavation along the base of an escarpment of Mineral Spring Branch. The escarpment face is rather steep and if the top of the exposure is the top of the limestone bed the overburden will be prohibitive a few feet back from the foot of the escarpment. Considerable quantities of the limestone could be worked along the lower edge of the escarpment, but not sufficient quantities to make the deposit of value except for local use. Also, the quality and distance from means of transportation prevent its being of commercial importance.

Shell Bluff (map locality Bu-6).—On the Savannah River, 40 miles below Augusta, is one of the classic exposures of the Georgia Coastal Plain. The strata exposed have been studied and described by various geologists within the past century. A hasty examination of the strata was made, during the field work, for this report, for economic rather than stratigraphic purposes. The following section is descriptive of the strata exposed:

Section of Shell Bluff, Savannah River, 40 miles below Augusta

	Feet
6. Covered with soil and humus; reddish clay sand exposed near top	100
5. Rotten, arenaceous limestone	22
4. Soft, arenaceous limestone; fossiliferous near top	8½
3. Soft, fossiliferous, arenaceous limestone	6
2. Rotten, cream colored, arenaceous limestone	9
1. Fossiliferous limestone; fossils hard, matrix soft	1½
River level	0
	147

The exposures of the strata are rather poor, making it necessary to work for some distance along the bluff in order to complete the section.

Samples of the stone show the following analyses:

Analyses of Samples from Shell Bluff, Savannah River

Sample No.	114	115
Soda (Na_2O)	.18	.15
Potash (K_2O)	.16	.14
Lime (CaO)	44.44	48.82
Magnesia (MgO)	.23	.32
Alumina (Al_2O_3) / Ferric oxide (Fe_2O_3)	.90	1.32
Phosphorus pentoxide (P_2O_5)	.10	.28
Silica (SiO_2) and insoluble	17.68	10.40
Undetermined	36.31	38.57
Total	100.00	100.00
Calcium carbonate ($CaCO_3$)	79.34	87.12
Magnesium carbonate ($MgCO_3$)	.46	.68
Total carbonates	79.80	87.80

Sample No. 114 was taken from 8 to 22 feet above the water and sample No. 115 from 22 to 47 feet above the water.

Dr. T. Wayland Vaughan has made a study of the Shell Bluff strata within recent years and places the limestone strata given in the above section in the Claiborne formation.[1]

Shell Bluff has a river frontage of more than 1000 feet, with the face of the bluff very steep. The limestone strata, which are largely covered by soil and humus, extend from the river surface to 47 feet above. There is no point where the overburden on the top of the limestone is light, hence only the stone along the face could be worked.

The nearest railroad is some 15 miles to the east, and, as a consequence, the only method of transporting the limestone would be by water. A wagon road could be built to the deposit, but owing to the steep face of the bluff it would be rather expensive.

[1] Geology of the Coastal Plain of Georgia: Bull. Ga. Geol. Survey, No. 26, 1911, p. 244.

The stone is of low grade, but, owing to its softness which makes it very cheaply worked, it could probably be used profitably for local agricultural purposes.

Utley Point Bluff (map locality Bu-7).—Limestone strata are exposed in Utley Point Bluff on the Savannah River one-half mile below Hancock Landing. The limestone is somewhat similar to that exposed in Shell Bluff 12 miles up-stream. See the foregoing locality description. The following section is descriptive of the strata exposed:

Section at Utley Point Bluff, Savannah River

	Feet
8. Mainly covered, a 6-foot bed of arenaceous limestone is exposed 50 feet above the river; large oyster shells overlie this bed	100
7. Hard, fossiliferous, glauconitic, arenaceous limestone	12½
6. Hard, fine grained, compact, dove colored limestone	1
5. Greenish gray laminated calcareous fullers earth	½
4. Ash colored, calcareous sand	1½
3. Fine grained, white, argillaceous limestone	½
2. Gray, calcareous sand	4
1. Talus	7
River	0
	127

A sample for analysis was taken from Bed No. 7, which gave the following results:

Analysis of Limestone Sample from Utley Point Bluff, Savannah River (Sample No. 116)

Soda (Na_2O)	.14
Potash (K_2O)	.08
Lime (CaO)	47.82
Magnesia (MgO)	.24
Alumina (Al_2O_3) } Ferric oxide (Fe_2O_3) }	2.64
Phosphorus pentoxide (P_2O_5)	.10
Silica (SiO_2) and insoluble	9.98
Undetermined	39.00
Total	100.00

Calcium carbonate ($CaCO_3$)	85.40
Magnesium carbonate ($MgCO_3$)	.50
Total carbonates	85.90

The strata here exposed are considered to belong to the Claiborne group. The only workable part of the limestone exposed is in a small shelf, covering one-half acre, of bed 7 of the above section. The only practicable means of transportation is the river. The nearest railroad is some 15 miles and the bluff face is so steep that a wagon road would be very expensive to construct. The quantity of the stone is so small that a plant to supply more than a very limited demand would soon exhaust the available supply.

Blue Bluff (map locality Bu-8).—A bluish, massive bedded, shell marl outcrops at the lower 15 feet of Blue Bluff on the Savannah River, 2 miles below Hancock Landing. Fossiliferous sand and clay overlie the marl for a thickness of 20 feet. From this point to the top of the hill, 75 feet above, the strata are concealed, but the roots of trees, which have been blown down, show red, argillaceous sand.

There is no workable material here, due to the low calcium carbonate content and the position under heavy overburden. However, a sample for analysis was taken from the lower marl bed.

Analysis of Marl Sample from Blue Bluff, Savannah River (Sample No. 117)

Soda (Na_2O)	.32
Potash (K_2O)	.27
Lime (CaO)	31.04
Magnesia (MgO)	.29
Alumina (Al_2O_3) Ferric oxide (Fe_2O_3)	2.72
Phosphorus pentoxide (P_2O_5)	.08
Silica (SiO_2) and insoluble	35.00
Undetermined	30.28
Total	100.00
Calcium carbonate ($CaCO_3$)	55.50
Magnesium carbonate ($MgCO_3$)	.60
Total carbonates	56.10

There are several other bluffs farther down-stream which show exposures of limestones and marls, but none are of economic importance. All of the exposures of strata in place have been studied by Veatch and Stephenson and the results published.[1]

SCREVEN COUNTY

All of Screven County with the exception of narrow strips along its main creeks and the Savannah River, is covered by sands and clays of the Altamaha formation. Numerous limesinks dot the northern portion of the county which, together with the long leaf pine, sandy soil with yellow or red clay-sand subsoil and rolling topography, gives it a very similar appearance to those regions in south and southwest Georgia immediately underlain by the Chattahoochee and Alum Bluff formations.

Limestones of Oligocene age outcrop in several localities along Beaver Dam and Briar creeks in the northern portion of the county. These exposures are described briefly as follows:

Jno. Reddick Place (map locality S-1).—Exposures of limestone occur on the John Reddick property, 1 mile northwest of Reddick's store and 6 miles northeast of Sylvania, near old Jacksonboro. The best exposure is the face of an old quarry near Beaver Dam Creek, one-fourth mile south of Blue Spring. Other outcrops are in the creek and spring. The following section is descriptive of the strata:

Section of Quarry on John Reddick Place, Screven County

	Feet
3. Soil and humus and unexposed overburden	27
2. Soft, white, granular limestone	6
1. Medium soft, white, granular, fossiliferous limestone	10
	43

The fossils of bed No. 1 are very poorly preserved and could not be determined. A sample taken from the entire quarry face shows

[1] Veatch, Otto, and Stephenson, L. W., Geology of the Coastal Plain of Georgia: Bull. Ga. Geol. Survey, No. 26, 1911, pp. 243-251.

the following analysis:

Analysis of Limestone Sample from Reddick Place, near Jacksonboro (Sample No. 118)

Soda (Na_2O)	.10
Potash (K_2O)	.05
Lime (CaO)	51.66
Magnesia (MgO)	.14
Alumina (Al_2O_3) / Ferric oxide (Fe_2O_3)	.42
Phosphorus pentoxide (P_2O_5)	.15
Silica (SiO_2) and insoluble	6.32
Undetermined	41.16
Total	100.00
Calcium carbonate ($CaCO_3$)	92.26
Magnesium carbonate ($MgCO_3$)	.30
Total carbonates	92.56

Dr. T. Wayland Vaughan visited this locality in 1902 and from the collection of fossils obtained he decided that the limestone was of Vicksburg age (Oligocene). The strata are evidently in their original position, dipping very slightly to the southeast.

The exposure under discussion occurs in a hillside quarry in the escarpment on the south side of Beaver Dam Creek. The quarry face is about 50 feet long and 15 feet high. At this height the limestone and soil overburden meet. The overburden reaches an apparent thickness of 27 feet some 50 or 75 feet back from the quarry face. It is quite probable that the limestone occurs at a higher elevation in the hill than is indicated by the exposure. The escarpment is practically continuous along Beaver Dam and Briar creeks and it is quite possible that prospecting would show up other deposits.

This deposit is about 6 miles from the nearest point on a railroad, but quite a large territory in the immediate vicinity of the exposure may be supplied with agricultural limestone if the deposit can be economically worked, which depends largely upon the thickness of the overburden.

This quarry was, according to Jack Reddick, worked before the Civil war, the stone being burned for lime, which was used for building purposes. One-fourth mile north of this old quarry, 2 or 3 feet of limestone is exposed in Blue Spring. The stone is the same as in the base of the quarry.

Haddocks Landing (map locality S-2).—At Haddocks Landing on Briar Creek, 1½ miles northeast of Reddick's store there is an exposure of several feet of limestone at the water's edge. This is a medium hard, pinkish, fossiliferous limestone similar, lithologically, to an outcrop in Spring Creek, Decatur County, 5 miles south of Brinson. The stone is at the foot of a steep, high escarpment. An old kiln on top of this hill is said to have been used in burning small quantities of stone from the deposit at the foot of the bluff.

WASHINGTON COUNTY

Washington County is overlain mainly by red and mottled argillaceous sand. Fossiliferous flint and fullers earth are exposed in the north central portion of the county and fullers earth and kaolin along Buck Creek and the Oconee River in the western portion. Limestone is exposed in several sinks and along the streams between Sandersville and Tennille, near Sunhill, and in the escarpment of the Oconee River in the southwestern part of the county.

The topography of the county is generally level to rolling with hills along Buck Creek and Oconee River.

B. T. Rawlings Place (map locality W-1).—Soft to medium hard, granular, argillaceous limestone containing fossils is exposed in several small sinks and along the branches on the B. T. Rawlings property, one-half mile south of Sandersville on the west side of the new Tennille road. The best exposure is in a well-like sink, 50 yards west of the public road and a few feet north of the farm road. Here 14 feet of limestone is visible, the lower part is rather hard while the upper part is somewhat softer. For 6 feet above the limestone the strata are covered. Above this there is a 2-foot ledge of sandstone exposed with 6 or 8 feet of soil overlying. One-fourth mile downstream, below a dam, calcareous sandstone underlies the limestone. The top of this sandstone is 25 feet below the top of the limestone at the sink near the road. At this exposure and at the 14-foot exposures in the sink, samples were taken for analyses, which gave the following results:

Analyses of Samples from B. T. Rawlings Place, One-half Mile South of Sandersville

Sample No.	97	98
Soda (Na_2O)	trace	.08
Potash (K_2O)	trace	.08
Lime (CaO)	52.00	51.38
Magnesia (MgO)	.04	trace
Alumina (Al_2O_3) / Ferric oxide (Fe_2O_3)	1.48	1.28
Phosphorus pentoxide (P_2O_5)	trace	.03
Silica (SiO_2) and insoluble	5.23	6.59
Undetermined	41.25	40.56
Total	100.00	100.00
Calcium carbonate ($CaCO_3$)	93.00	91.70

Sample No. 97 was taken from the 14-foot exposure at the sink, and sample No. 98 from the 5-foot exposures below the dam.

This limestone was correlated with the Claiborne formation by Veatch and Stephenson in their report on the Geology of the Coastal Plain of Georgia. This, however, seems to be doubtful, according to the information gathered during the field work for this report. The exposures are not sufficiently extensive to determine the dip of the strata; however, it is probably a few feet per mile to the southeast.

The Sketch map (Fig. 1) will serve to give an idea of the extent and conditions under which the deposit occurs. At A there is a 14-foot exposure of limestone in a sink. Running west from the bottom of the sink there is a subterranean stream channel which is said to

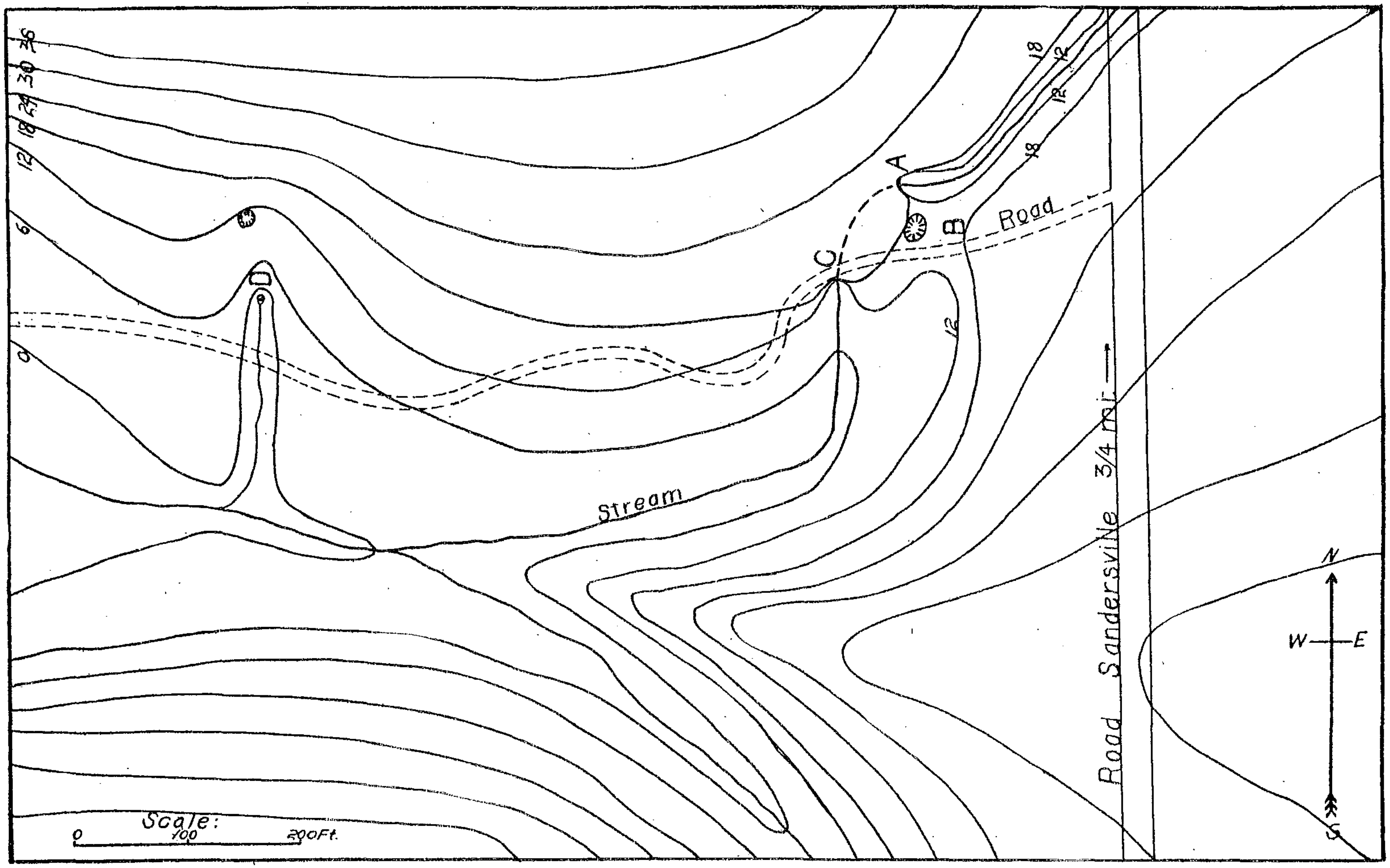


Fig. 1.—Sketch map of B. T. Rawlings property, near Sandersville, Washington County, Georgia

have been passable at one time for several hundred feet. Fifty feet southeast of this sink the farm road passes over a small area of limestone, at B. Surrounding this exposure there is a practically level area of about one-half acre. Fifty feet west the limestone is again exposed in a well-like sink for a thickness of 10 feet. At C is a third exposure with a thickness of 8 feet. The immediate overburden surrounding the 4 exposures mentioned in this paragraph is about 1 foot. Going northwest up the side of the escarpment as indicated by the contour lines on the sketch the overburden will, of course, get heavy.

Some 500 feet west of the above group of exposures the limestone is exposed in a small spring, D. This exposure is 3 feet lower than the base of the exposure A. Hence, the limestone should occur in the escarpment just west of the spring at least 17 feet above the level of the spring. It is exposed in a sink 25 feet west of D and 9 feet above, under 1 foot of soil and humus. Between C and D on the gentle slope of the escarpment there are no exposures, but prospecting would probably show limestone a foot or two beneath the surface. No limestone is visible in the escarpments west of D or south across the branch.

Exposures occur in the southern escarpment of the branch below the dam, one-fourth mile west of A. The base of the limestone here is about 11 feet below the base at A, therefore the bed has a probable thickness of about 25 feet.

These deposits could be worked to the level of the branch and natural drainage retained. The Augusta Southern Railroad is about one-half mile east of the deposits.

It is seen from the above discussion and the sketch that the quantity of available limestone in this deposit is not great and that it is located some distance from means of transportation. However, the fair quality of the stone, as seen from analyses, and the ease with which it can be worked, being soft and with light overburden, should make it of considerable importance for local agricultural uses.

Wall and Pittman Properties (map locality W-2).—Exposures of medium hard, fossiliferous limestones occur along several small branches in deep ravines on the Wall and Pittman properties, 2 miles northwest of Tennille and 2 miles south of Sandersville. None of these outcrops exceed 4 or 5 feet in thickness, but they can be traced for some distance along the streams. They lie at the foot of very steep escarpments. The overburden on all of these exposures is too great to allow economic exploitation. However, it is possible that there are other deposits in this section which could be worked economically for local use.

C. D. Thigpen Property (map locality W-3).—There is a small exposure of limestone at the foot of a steep escarpment in and near a small pit on the C. D. Thigpen property, one-eighth mile southeast of Sunhill Station. The following section is here exposed:

Section on Thigpen Property, Sunhill, Washington County

	Feet
5. Red argillaceous sand	10
4. Medium grained, white sand grading into yellow sand	5
3. White, calcareous clay	2
2. Arenaceous limestone or calcareous sandstone	3
1. Hard, white, compact, partly crystalline limestone	9
	29

The limestone exposed in bed No. 1 of the above section has a compact, uniform texture and an irregular fracture. The stone is hard, but not tough. A sample of the stone from the upper 6 feet of the bed shows the following analysis:

Analysis of Sample from Sunhill
(Sample No. 17)

Soda (Na_2O)	.04
Potash (K_2O)	.10
Lime (CaO)	52.85
Magnesia (MgO)	.04
Alumina (Al_2O_3) / Ferric oxide (Fe_2O_3)	.86
Phosphorus pentoxide (P_2O_5)	.04

Silica (SiO_2) and insoluble	3.78
Undetermined	42.29
Total	100.00
Calcium carbonate ($CaCO_3$)	94.35

According to Veatch and Stephenson this limestone bed belongs to the Claiborne group. It occurs here at the base of a low plateau rising about 40 feet above the creek beds. The only fossils seen were two species of a small delicate pecten radially ribbed. No data as to the dip of the beds could be secured, but they probably dip slightly to the southeast. The limestone is immediately overlain, apparently conformably, by white sands and clays with red sands and mottled arenaceous clays topping the plateau. The total thickness of limestone exposed in or near this quarry is 9 feet, only 3 feet of which, however, is shown in the quarry. Another 3 feet is exposed in a spring a few feet to the west while the upper 3 feet is exposed in the face of the escarpment. None of the exposures are more than a few feet in length. This limestone is in the horizon of the gentle sloping south and east sides of the escarpment, but no more exposures occur.

It is seen from the section above that the limestone bed in the escarpment is covered by 20 feet of overburden. This overburden is much too heavy to allow economic working unless the stratum of limestone is of much greater thickness than that exposed. Drilling is necessary to determine this thickness. A spring 25 feet from the foot of the bluff shows the overburden to be 2 feet and it is possible that this thickness continues almost to the creek, 100 feet north. This flat along the foot of the ridge continues for some distance down the creek, but the steep escarpment is only 250 feet, west to east. Prospect pits are necessary to determine the overburden in this bottom and the gentle slopes on the east and south sides of the ridge.

The analysis shows a high-calcium limestone carrying small percentages of potash and phosphate, all of which go to make it an excellent stone for agricultural purposes. The stone is hard and would not be easily powdered in handling after being burned, which, together with its high calcium oxide would make it a fair material for the manufacture of lime for building purposes. It would also make a good aggregate for concrete and road metal.

Northington Place (map locality W-4).—Limestone is exposed on the Northington place, 2 miles south of Oconee and 1 mile east of the Oconee River. The outcrop occurs in a well-like sink at the foot of the second river terrace escarpment, which is about 1 mile east of the river at this point. The exposure is in such a position in the sink that no sample for analysis could be secured. The stone is hard and white and very similar to that at Sunhill. White to yellow sand overlies the limestone. A complete section could not be made, but it is apparently very similar to that at Sunhill, given in the preceding locality description.

JOHNSON COUNTY

Johnson County is largely within the terranes of Oligocene and later formations with a narrow belt along the Oconee River in which Eocene strata are exposed. The only known exposure of limestone occurs at Wring Jaw Landing.

Wring Jaw Landing.—McCallie[1] has furnished the following section, descriptive of the strata exposed in the bluff at Wring Jaw Landing on Oconee River, 2 miles west of Kittrells.

Section at Wring Jaw Landing

Jackson group.	Feet
8. Massive, red, sandy clay	8
7. Stratified, red, sandy clay	8
6. Bluish, lignitic clay	8
5. White and yellow sands	4
4. Bluish clay with fossil leaves	4
3. Hard, glauconitic limestone, fossiliferous	8
2. Bluish clay with fossil shells	2
1. Soft glauconitic limestone or marl	

No analyses of the limestone and marl of this section are available.

[1] Geology of the Coastal Plain of Georgia: Bull. Ga. Geol. Survey, No. 26, pp. 305-306.

WILKINSON COUNTY

Wilkinson County is within the terranes of Lower Cretaceous, Claiborne and Jackson groups. The surface is composed mainly of red, clayey sands. No exposures of limestone within the county are known and but few outcrops of marl.

Toomsboro.—H. K. Shearer has furnished the following section of exposures on the property of Dr. N. T. Carswell, 3 miles west of Toomsboro, near the Central of Georgia Railway.

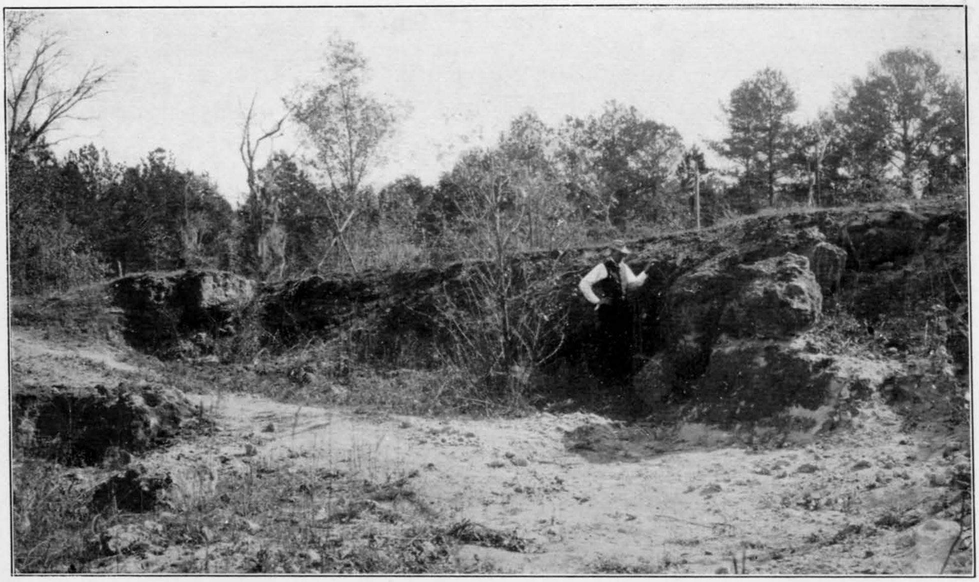
Section on Carswell Property, near Toomsboro

	Feet
Eocene.	
5. Residual red sands cap the high hills.	
Jackson group.	
4. Fullers earth	10+
3. Hard and soft, yellow, argillaceous, Bryozoan marl. .	20+
Unconformity.	
Lower Crectaceous.	
2. Bauxite lenses.	
1. Kaolin and kaolinic sands.	

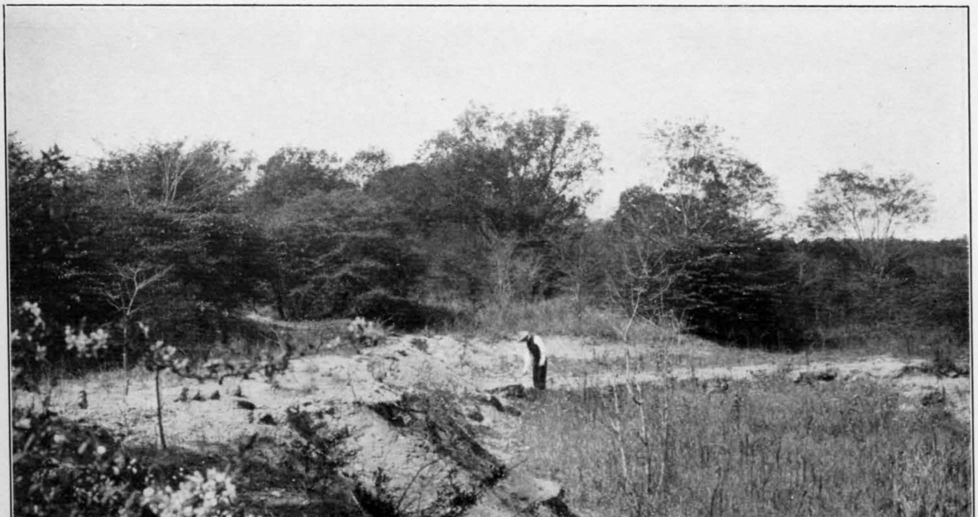
No analysis of this marl by the Survey is available but it is said to contain from 45 to 50 per cent calcium carbonate. Other exposures of marls similar to this one occur in the county, according to Shearer.

BLECKLEY COUNTY

The limestone exposures of Bleckley County are confined to a narrow belt along the extreme northern boundary, being the southern extension of the Jackson limestone in Twiggs County. The principal stone is a soft, white, porous, friable limestone composed almost entirely of fossils. Slightly harder limestone of the same character and hard, white to pinkish, partly crystalline, fossiliferous limestone, together with cream colored or blue fullers earth and varicolored argillaceous sands and flint, overlie the lower limestone bed in the order named. The general section is given in the locality descriptions below.



A. OLD LIMESTONE QUARRY, 3½ MILES SOUTH OF PERRY, HOUSTON COUNTY.



B. LIMESTONE EXPOSURE ON MOSSY RIDGE, 5 MILES SOUTH OF PERRY, HOUSTON COUNTY.

The main limestone beds, the lowest and the one overlying, are comparatively pure, soft, friable, and easily worked. As in Houston and Twiggs counties the exposures occur along the base of the escarpments, in steep bluffs and as low ridges and terraces.

Weatherly Place (map locality Bl-1).—An exposure of Jackson limestone occurs in the steep escarpment on the east side of Shellstone Creek, one-half mile southeast of the public road, 1¼ miles east of Ainslie Station. The following section is exposed at this point:

Section East Bank of Shellstone Creek, near Ainslie Station

	Feet
Oligocene (?).	
6. Red argillaceous sands to top of escarpment. There is no sharp line of contact between this and underlying bed.	
Eocene.	
Jackson group.	
5. Cream colored fullers earth with some sand........	20
4. Hard, pinkish, partly crystalline limestone; fossiliferous, Turritella most prominent..............	1
3. Medium hard, white, porous limestone. Fossils numerous	5
2. Soft, white, porous, friable limestone, highly fossiliferous	15
1. Creek bottom land.............................	3
	44

A sample from a weathered exposure of the lower limestone bed shows the following analysis:

Analysis of Sample from Weatherly Place
(Sample No. 2-B)

Soda (Na_2O)	trace
Potash (K_2O)	trace
Lime (CaO)	52.34
Magnesia (MgO)	.12
Alumina (Al_2O_3) } Ferric oxide (Fe_2O_3) }	.98
Phosphorus pentoxide (P_2O_5)....................	trace
Silica (SiO_2) and insoluble.....................	4.69
Undetermined	41.87
Total	100.00

Calcium carbonate ($CaCO_3$)	93.44
Magnesium carbonate ($MgCO_3$)	.26
Total carbonates	93.70

The residue, insoluble in hydrochloric acid, consists of clay, clear quartz grains .1 to .3 mm. in diameter and siliceous and glauconitic casts of Bryozoa about .1 mm. in diameter and .5 to .8 mm. long

The escarpment, in which the above section occurs, has a slope of about 30° from the foot to the upper limit of the fullers earth, bed 5 of the section. This means that the overburden of clay on the limestone is too heavy to allow economic working. The bluff has an extent of 600 feet northeast and southwest. Prospecting on the more gentle slopes adjacent to the bluff would possibly prove up a workable deposit of limestone, but even if this be the case the distance from a railroad, 1¼ miles, is too great for the deposit to be of economic importance except for local use.

Ainslie Station (map locality Bl-2).—On the E. B. Weatherly place, in the northwestern part of Bleckley County, limestone deposits occur in two low ridges or benches extending westward from the foot of a high escarpment, 200 yards east of Ainslie Station. The principal limestone is soft, white, porous, and friable, composed largely of Bryozoa, Orbitoides, and *Pecten perplanus*. A harder stone of the same general character, but containing a larger variety of fossils, is also present. The general section is as follows:

Section at Ainslie Station, Bleckley County

	Feet
4. Vari-colored, argillaceous sand	15
3. Cream colored, calcareous fullers earth	20
2. Limestone	25
1. Bottom land, black soil	0
	60

The similarity between this section and those given in above locality descriptions is quite marked. No sharp line of contact can be seen between the clay and the overlying sands.

The stone at these deposits is not visible in place, but as loose boulders and fragments covering the surface. By digging through a few inches of black soil, however, the solid limestone may be seen. The larger of the deposits, 300 yards southeast of the station, covers an area of 5 acres, with a maximum thickness of 25 feet. The average thickness is much less than here given, due to the gently sloping sides of the terrace. Continuing up the escarpment from the upper limit of limestone there is a gently sloping area covering 2 acres with an average of a 4-foot clay overburden. Beyond this area the escarpment is rather precipitous.

Across a shallow valley 100 yards north of this deposit there is another spur covering 1½ acres, with limestone on the surface as described above. The upper limit of the stone here is at the same elevation as in the deposit to the south, while the lower limit is 5 feet above, due probably to the meadow being higher at this point. This gives a maximum thickness of 20 feet of limestone with the average about half as great. The overburden consists of a few inches of soil and limestone fragments. Beginning at the top of this deposit there is a comparatively level tract of 5 acres with an average elevation of 4 or 5 feet above the limestone. Farther east the escarpment face is steep.

Other ridges similar to the above two occur along the escarpment within a distance of three-fourths mile, but no limestone is visible. Prospecting is necessary to determine the extent of the underlying limestone.

J. T. Deese Property (map locality Bl-3).—Limestone occurs on the property of J. T. Deese, 10 miles north of Cochran. The exposures are along an escarpment on the southeast side of Shellstone Creek on land lots 204 and 217 of the 24th district of Bleckley County. The limestone has a stratigraphic thickness of 11 feet, the lower 6 feet of which is soft, very porous, cream colored and friable, composed almost entirely of Bryozoa and numerous Orbitoides, Pecten, Periarchus and other fossils. The upper 5 feet consists of a harder stratum of stone of the same general character, but containing a much greater variety of fossils. Overlying the limestone is a foot or two of soil.

In the bed of a small tributary of Shellstone Creek, coming in from the south near the northeastern end of the limestone bluff, a 30-foot bed of blue fullers earth-like clay is exposed immediately above the limestone. This material occurs at the same horizon in the formation as the cream colored clay just above the limestone at other described localities in Bleckley, Twiggs and Houston counties. This exposure is comparatively fresh and unweathered, and is probably the original type of material from which the cream colored fullers earth was derived.

A sample taken from the entire thickness of the limestone bed shows the following analysis:

Analysis of Limestone Sample from the Deese Place (Sample No. 21)

Soda (Na_2O)	trace
Potash (K_2O)	trace
Lime (CaO)	53.02
Magnesia (MgO)	trace
Alumina (Al_2O_3) } Ferric oxide (Fe_2O_3) }	2.24
Phosphorus pentoxide (P_2O_5)	.04
Silica (SiO_2) and insoluble	3.71
Undetermined	40.99
Total	100.00
Calcium carbonate ($CaCO_3$)	94.72

The residue left from the solution of the limestone in hydrochloric acid is composed of greenish glauconitic casts of Bryozoa and minute siliceous sponge-like casts. Quartz grains are scarce.

The deposit is in the upper part of the lower limestone bed of the Jackson group. The outcrop gives no evidence of disturbances which have altered the original position of the strata. No joints apparently have been developed.

As mentioned in a preceding paragraph, the visible deposit has an average thickness of about 11 feet with a horizontal extent of about 1000 feet. The creek swamp is at the base of the outcrop while Shellstone Creek itself is 2 to 3 feet lower. This indicates that the entire thickness of the exposure may be worked and natural drainage retained. If the workings are sunk below the level of the creek, however, mechanical means of drainage must be resorted to.

The immediate overburden consists of 1 to 2 feet of soil. Extending southeastward from the edge of the escarpment there is a level area approximately 1000 feet wide. No exposures of stone occur over this area, hence no definite idea of the thickness of the overburden could be obtained. It is, however, probably not more than a very few feet, provided the strata dip only a few feet per mile to the southeast. Certain exposures of the continuation of this limestone bed in Twiggs and Houston counties show an average stratigraphic thickness of about 45 feet. There is every reason to believe that the deposit has about the same thickness in this locality.

The stone is of excellent quality for agricultural purposes, but its physical character makes it unsuitable for most other uses. The distance of the deposit from a railroad, about 3 miles, decreases its value as a commercial proposition. It is, however, admirably suited for development for local use.

TWIGGS COUNTY

The limestone exposures of Twiggs County occur at wide intervals throughout the entire county with the exception of a narrow strip down the Ocmulgee River, the western boundary, and along the creeks in the northern portion of the county. The most important variety is a soft, white to cream colored, very porous, friable limestone composed almost entirely of Bryozoa and numerous other fossils among which are Orbitoides, Echinoids, Pecten, Leda, Protocardia, and Corbula. The beds are frequently glauconitic. Immediately overlying this soft stone in the southern portion of the county is a hard, white to cream or pinkish colored, partly crystalline limestone containing scattered fossils, the most prominent of which is Turritella. Analyses of various samples taken from the different exposures of the soft limestone show calcium carbonate contents varying from 80 to 97 per cent.

The above limestone bed occurs at the base of the Jackson group and is made up of alternating layers of soft and slightly harder stone with no distinct bedding planes. The softer stone makes up the greater portion of the bed. The strata exposed are apparently in their original position, dipping slightly to the southeast. There are no outcrops in the county of sufficient extent parallel to the direction of the dip to allow the determination of the slope of the beds. Exposures in the banks of the Ocmulgee River about 15 miles to the south show a dip of 8 to 12 feet per mile to the southeast.

Immediately overlying the limestone is a bed of calcareous fullers earth from 45 to 90 feet thick, frequently containing thin layers of both original and apparently concretionary limestone. The clay is cream colored on its weathered surface and blue below the zone of weathering or the level of the ground water. Red sands, mottled, arenaceous clays and flint, all probably residual of Oligocene formations, overlie the clay and continue to the surface of the plateaus, which are frequently 200 feet above the limestone in the northern portion of the county.

The topography of Twiggs County is comparatively rugged, having high, precipitous scarps and deep, narrow valleys. In the northern portion of the county Cretaceous clays and sands lie along the base of the escarpments with the Jackson limestone and fullers earth overlying. The residual red and mottled argillaceous sands and flint of Oligocene age lie immediately above the Jackson strata and cap the ridges and plateaus. In the southern portion the limestone occurs at the base of the hills with the sands and flint overlying.

The workable limestone deposits occur in creek bluffs and low ridges, benches and terraces which extend out from the foot of the escarpments. Up to the present time no development work has been done on the limestone of this county, although the material is admirably suited for use in agriculture, as may be seen from the analyses accompanying the following locality descriptions:

Lowe Wall Property (map locality T-1).—On the property of Lowe Wall, 2 miles southeast of Pikes Peak Station, there are several exposures of limestone near the western end of a low ridge, on the northeast side of the road, one-fourth mile southeast of the Adam Burkett residence. The best of these outcrops is in a 12-foot vertical face of a gully, on the north side of the ridge, 100 yards from the road. The stone is soft, white, friable, massive bedded limestone, composed almost entirely of Bryozoa with a few Pecten and Periarchus. A good exposure of the underlying stratum is not visible, but it seems to be sand. The tough, black, clay-soil on the ridge indicates the presence of fullers earth above the limestone. A comparison of the descriptions of the above exposure and those of the southern portions of Twiggs and Houston counties shows the close similarity between the materials.

The other exposures around the end of this limestone ridge show the same type of stone, together with a harder stone containing fewer fossils. These outcrops conform to the general slope of the hillside. A sample of the stone from the gully shows the following analysis:

Analysis of Limestone from Lowe Wall Property
(Sample No. 101)

Soda (Na_2O)	.15
Potash (K_2O)	.08
Lime (CaO)	48.72
Magnesia (MgO)	.20
Alumina (Al_2O_3), Ferric oxide (Fe_2O_3)	1.16
Phosphorus pentoxide (P_2O_5)	.06
Silica (SiO_2) and insoluble	11.35
Undetermined	38.28
Total	100.00
Calcium carbonate ($CaCO_3$)	89.00
Magnesium carbonate ($MgCO_3$)	.40
Total carbonates	89.40

This limestone belongs to the Jackson group. The strata apparently occupy their original position, dipping slightly to the southeast. No joints have been developed.

The outcrops of the stone on this ridge are not sufficiently extensive to give a conclusive idea of the character of the deposit. The maximum thickness exposed is 12 feet. Other exposures occur around the end of the ridge, conformable to the gentle slope. The base of the limestone exposed is above the bottom of the gully in which it occurs and is, therefore, above drainage level.

The top of the hill, 150 feet east of the gully exposure, is 30 feet above the top of the stone, which indicates the thickness of overburden. On the south side of the ridge the slope is more gentle, there being an area of an acre or more upon which there is practically no overburden. The quality of the stone and the distance from a railroad probably preclude it from being of commercial importance, except locally.

Three Miles Southeast of Stony Creek Church (map locality T-2).—There is a deposit of limestone 3 miles southeast of Stony Creek church near an old railroad right-of-way. The exposures occur in the sides of a gully 100 yards south of the right-of-way. The principal stone is the soft, white to cream colored, friable limestone composed almost entirely of Bryozoa with Pecten, Periarchus, and occasionally other fossils. The following section was observed at this exposure:

Section 3 Miles Southeast of Stony Creek Church

Jackson group.	Feet
3. Gray fullers earth overlain by tough, black clay-soil	6
2. Soft, white, fossiliferous limestone containing thin, medium hard layers; lower 2 feet argillaceous...	16
1. Argillaceous sand	2
	24

The marked similarity between this section and those seen in the southern portions of Twiggs and Houston counties may be readily observed by comparison. A sample from the limestone bed shows the following analysis:

Analysis of Limestone Sample from 3 Miles Southeast of Stony Creek Church (Sample No. 102)

Soda (Na_2O)	.28
Potash (K_2O)	.14
Lime (CaO)	44.08
Magnesia (MgO)	.46
Alumina (Al_2O_3) / Ferric oxide (Fe_2O_3)	2.20
Phosphorus pentoxide (P_2O_5)	.06
Silica (SiO_2) and insoluble	16.89
Undetermined	35.89
Total	100.00
Calcium carbonate ($CaCO_3$)	78.70
Magnesium carbonate ($MgCO_3$)	.95
Total carbonates	79.65

These strata belong to the Jackson group. No disturbances of the original position of the strata seem to have taken place.

The limestone outcrops continuously in a gully for a distance of 150 yards, on the east side of which there is an area of about 4 acres underlain by the stone at a probable depth of 6 feet, but farther back from the exposure the overburden is much heavier. West of the gully a 3-acre area slopes very gently from 2 feet above the limestone to the base of the bed. The entire deposit is above drainage level.

This deposit is at too great a distance from the railroad and the quantity of limestone under a light overburden is too small to be of commercial value except for local agricultural use. The calcareous material can be very advantageously used in its present condition. The exposed stone can be easily worked with a pick and shovel and readily breaks down to a size suitable for agricultural use.

One and One-fourth Miles South of Bond's Store (map locality T-3).—In a deep gully on the east side of the public highway, 1¼ miles south of Bond's store, there is a 13-foot exposure of soft, white to cream colored, friable, massive bedded limestone of Jackson age composed almost entirely of Bryozoa with Pecten, Periarchus and other fossils. Yellowish fullers earth immediately overlies the limestone with red and mottled sands and clay-sands above to the top of the hill, which is about 100 feet above the limestone. The exact thickness of the fullers earth could not be determined, but it is at least 25 feet. The elevation of the top of the limestone is 455 feet above sea level, according to aneroid barometer reading. This deposit is of little economic importance on account of the thickness of the overburden.

Wimberly Place (map locality T-4).—Jackson limestone is exposed in a creek escarpment known as Oak Ridge, 4 miles east of Adams Park on the property of Minter Wimberly.

The exposure has a maximum thickness of 20 feet with 14 feet of massive, soft, white, porous, highly fossiliferous limestone at the base and 6 feet of slightly harder limestone of the same general character overlying. Both of these beds are slightly glauconitic. Fragments of hard, white crystalline limestone occur on and in the thin soil on top of the ridge. A sample taken from the lower bed shows the following analysis:

Analysis of Sample of Limestone from Wimberly Place
(Sample No. 16)

Soda (Na_2O)	.02
Potash (K_2O)	.09
Lime (CaO)	51.56
Magnesia (MgO)	.08
Alumina (Al_2O_3) } Ferric oxide (Fe_2O_3) }	1.14
Phosphorus pentoxide (P_2O_5)	.08
Silica (SiO_2) and insoluble	7.29
Undetermined	39.74
Total	100.00
Calcium carbonate ($CaCO_3$)	92.06

The residue insoluble in hydrochloric acid consists of clear quartz grains .05 to .1 mm. in diameter, glauconitic casts of Bryozoa, and clay.

The escarpment has a maximum elevation above the creek swamp of 27 feet. The lowest limestone exposure in place is 6 feet above the swamp and the highest 26 feet, giving a thickness of 20 feet of limestone underlying an overburden of 1 to 2 feet. The steep escarpment is continuous along the edge of the swamp for a distance of 1200 to 1500 feet. The top of the ridge is practically level for a distance of several hundred feet at the southern end and about 1500 feet at the northern end. These figures are rough estimates and are only intended to give a general idea of the extent of the deposit.

The fragments of hard, partly crystalline limestone which occur on top of the ridge indicate that the 20-foot exposure is the upper part of the lower Jackson limestone. In Houston County the hard limestone is found immediately on top of a 45-foot bed of soft fossiliferous limestone. Should this condition obtain on the Wimberly property it would seem that there is a thickness of about 25 feet of limestone below the lowest exposure in the escarpment.

In working this deposit the quarry will have natural drainage if the floor is kept slightly above the creek swamp. The distance from a railroad prevents it from being developed on a large commercial scale at the present, but it is well situated for development for local agricultural uses. The stone is too soft and impure to be used for most of the other purposes to which limestones are adapted.

Wimberly Place, 4 miles east of Adams Park (map locality T-5). —The road from the plantation quarters on the Minter Wimberly place to Adams Park crosses an area covered by limestone fragments of the east side of Savage Creek, 2 miles west of the quarters. The fragments consist of soft, white, porous, highly fossiliferous, friable limestone, similar to and at the same horizon as the exposure at Oak Ridge, 1 mile north.

These fragments occur on the surface of a low limestone ridge covering one acre and extending westward from the main high escarpment. The limestone occurs over a stratigraphic thickness of 18 feet, with the lower limit 6 feet above the surrounding meadow. Cream colored fullers earth overlies the limestone and continues for some distance up the side of the escarpment. No exposures of the limestone in place occur, but by digging through about 6 inches of soil the solid stone may be struck at almost any point on the ridge.

It is quite probable that the greater thickness of limestone occurs beneath the lower limit of the stone as seen. Natural drainage can be secured by keeping the floor of the quarry above the level of the meadow, which would give a maximum thickness of 25 feet of limestone.

Across a shallow valley, 100 yards north of the above deposit, is another limestone ridge similar to the one near the road, but covering only about one-half acre. In addition, two other small limestone spurs similar to the above occur one-fourth mile north of the road which, together, cover an area of about one acre.

No exposures in place occur on any one of the above ridges, but the solid limestone is usually found from 6 inches to 1 foot beneath the soil. No satisfactory sample for analysis could be obtained, but the sample taken on Oak Ridge from similar limestone at the same horizon gives an idea of the chemical character of the stone.

Fitzpatrick Place (map locality T-6).—A small ridge of Jackson limestone occurs on the Irwin Fitzpatrick place, 3 miles northeast of West Lake on the plantation road from the latter place to Tarversville. The ridge is covered with fragments of soft, white, porous, highly fossiliferous limestone with a few small natural exposures in the road, 10 feet above the lower limit of the loose material. The stone is made up entirely of Bryozoa, Echinoids, Pecten, and other fossils, named in the order of their importance. Some of the layers are slightly glauconitic. The stone is in every way similar to that at the other localities in Twiggs and Houston counties, and is apparently at the same horizon. A sample taken from one of the small, slightly weathered exposures in place shows the following analysis:

Analysis of Sample from Fitzpatrick Place, 3 Miles Northeast of West Lake (Sample No. 14-A)

Soda (Na_2O)	.10
Potash (K_2O)	.14

Lime (CaO)	48.88
Magnesia (MgO)	.16
Alumina (Al_2O_3) / Ferric oxide (Fe_2O_3)	1.58
Phosphorus pentoxide (P_2O_5)	.08
Silica (SiO_2) and insoluble	8.28
Undetermined	40.78
Total	100.00
Calcium carbonate ($CaCO_3$)	87.28
Magnesium carbonate ($MgCO_3$)	.34
Total carbonates	87.62

The residue insoluble in hydrochloric acid consists of partially rounded grains of clear quartz, and glauconitic casts of Bryozoa .05 to .1 mm. in diameter.

This deposit has a maximum thickness of 20 feet above the level of the bottom land. At and below the upper limit of the limestone a few fragments of hard, partly crystalline limestone occur, above which is cream colored fullers earth. This indicates that the stone belongs to the upper part of the 45-foot bed of limestone exposed at various places in Twiggs and Houston counties. The exact thickness of the bed in this section of Twiggs County could not be determined, however, it is probably not far from that given for other exposures—45 feet. The ridge covers an area of slightly more than 1 acre, with an overburden of not more than a foot or two. Figure 2 shows the general contour and size of the ridge.

On either side of this deposit there are other low ridges extending westward from the foot of the high escarpment. No limestone is in sight, but it is possible that prospecting would show an overburden light enough to allow economic working of the underlying limestone.

Fitzpatrick Place (map locality T-7).—On the property of Irwin Fitzpatrick, 2½ miles north-northeast of West Lake there is a low ridge extending southeast from a higher ridge, covered with waterworn fragments of limestone. There are two types of stone of Jackson age, one a hard, cream colored, partly crystalline limestone containing Bryozoa, and the other a soft, white, porous, friable limestone made up of Bryozoa, Echinoids, Pecten, and other fossils. The latter was seen in a flat exposure in place covering only a few square feet.

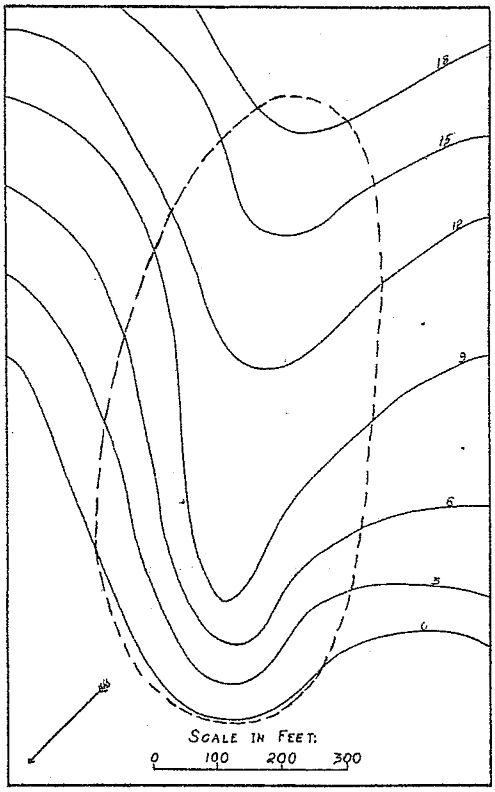


Fig. 2.—Sketch map of limestone ridge on Fitzpatrick property, Twiggs County. Limestone fragments within dotted lines.

An average sample of the stone could not be obtained, but the analysis of a sample taken 1 mile east, from the same variety of material, will serve to give an idea of its chemical character. (See analysis of sample in above description.)

Figure 2 is a sketch of a limestone deposit that will answer the purpose of a general sketch for the deposits of limestone in Twiggs and Houston counties described as occurring in "ridges" or "spurs."

The fragments of limestone are scattered over practically the entire surface of the ridge, covering an area of about 8 acres. The upper limit of the stone is 25 feet above the surrounding bottom land, while the lower limit is 3 feet above, giving a maximum thickness of 22 feet. The average thickness, however, is only slightly more than half as great, due to the gently sloping hillsides.

The exact horizon of this exposure could not be determined. An exposure of cream colored fullers earth on the slope of the main escarpment, northwest of the limestone, is about 15 feet above the top of the stone in sight. No exposures occur between the clay and the limestone. The deposit 1 mile east of this exposure is in the upper part of the Jackson limestone. Since the valleys between the ridges are at about the same elevation above the creek it seems probable that this deposit is also in the upper part of the 45-foot bed of limestone which occurs at the base of the Jackson group.

McRae Place (map locality T-8).—On the old McRae place, 2½ miles east of West Lake and one-half mile west of the West Lake-Tarversville public highway, there is a limestone deposit in a low ridge extending westward from the main escarpment to within a few hundred feet of Crooked Creek. A few very poor exposures in place of soft, white, porous, friable limestone composed of Bryozoa, Orbitoides, Echinoids, Pecten, and other fossils were seen. Small pieces of this material and hard, partly crystalline limestone with a few fossils are scattered over the entire ridge. Both varieties of the stone are exactly similar to those at other localities in Twiggs and Houston counties which are of Jackson age as determined by the fossils.

Owing to the weathered condition of the limestone exposed, no sample for analysis was taken. The analysis of the stone obtained from the exposure on the Fitzpatrick place, three-fourths mile north, will serve to give an idea of the composition of the material.

The general contour of the ridge is shown by the sketch, Fig. 2. The limestone in sight occurs over an area of about 6 acres, and has a stratigraphic thickness of 18 feet. The average, however, is much less, as may be seen from the sketch. From the upper limit of limestone to the top of the ridge to the east there are no exposures in place, and as a consequence the horizon of the limestone could not be determined. The presence, however, of the hard, partly crystalline limestone indicates that this is the upper part of the limestone bed at the base of the Jackson.

In working this deposit natural drainage may be retained by keeping the floor of the quarry slightly above the creek bottom. The limestone is about 2 miles east of the nearest point on the Southern Railway.

BIBB COUNTY

The northern portion of Bibb County is within the Crystalline area while that portion south of Macon, except the southeast corner, is within the terrane of the Cretaceous formations. In the southeastern part of the county there are exposures of Tertiary strata. Limestones and fullers earth of the Jackson group are exposed along the base of the hills while red and mottled argillaceous sands, sandstone and flint, largely residual, cap the ridges and plateaus. This section of the county is very much dissected, there being steep hills and ridges rising 100 to 200 feet above the usually narrow valleys.

Ard Property (map locality B-1).—Exposures of limestone occur on a knoll 1 mile east of old Bond post office and 2 miles south of Swift Creek Station, on the Ard property. There are two varieties of stone occurring here, a thin layer of hard, white, partly crystalline limestone and beneath, a bed of soft friable limestone composed entirely of Bryozoa and other fossils among which the most important are *Pecten perplanus* and Periarchus. This stone is similar in every way to that of the exposures in Houston, Bleckley, and Twiggs counties. A black and yellow tough clay derived from fullers earth overlies the limestone.

A rather poor representative sample of the limestone shows the following analysis:

Analysis of Limestone Sample from Ard Property (Sample No. 19)

Soda (Na_2O)	.06
Potash (K_2O)	.10
Lime (CaO)	46.12
Magnesia (MgO)	.04
Alumina (Al_2O_3) / Ferric oxide (Fe_2O_3)	2.20
Phosphorus pentoxide (P_2O_5)	.04
Silica (SiO_2) and insoluble	13.84
Undetermined	37.60
Total	100.00
Calcium carbonate ($CaCO_3$)	85.92

A. LIMESTONE AND FULLERS EARTH OUTCROP ON SMALL PROPERTY, 4½ MILES EAST OF KATHLEEN, HOUSTON COUNTY.

B. LIMESTONE BOULDERS ALONG PERRY-ELKO ROAD, 3½ MILES SOUTH OF PERRY, HOUSTON COUNTY.

This analysis shows a lower calcium carbonate content than is usual for this type of stone, but this is probably due to the fact that it was secured on partially weathered exposures.

The limestone of this deposit belongs to the Jackson formation, being the upper part of the limestone bed which occurs at the base of the formation. The strata seem to occupy their original position, dipping slightly to the southeast.

The outcrops of limestone are scattered over the surface of a low knoll, which covers an area of 2 or 3 acres, and in a small excavation on the south slope of the hill. The lowest exposure is in the base of the excavation, while the highest is near the top of the knoll which gives a total exposed thickness of 14 feet. The upper exposure is probably the top of the bed, while it is possible that the bottom of the pit is some distance above the base of the limestone bed, although in the northern part of Twiggs County to the east of this exposure, the bed is only from 12 to 15 feet thick. A bed 40 feet thick could be worked before mechanical drainage would be necessary. The burden overlying the stone for the area given is probably not more than a foot at any point.

The distance of this deposit from transportation, 2 miles, greatly decreases its commercial value, but it is well located for local agricultural uses. The stone removed in the small excavation on the side of the hill was burned for lime for building purposes some 40 or 50 years ago, according to information received.

HOUSTON COUNTY

The limestone exposures of Houston County are confined to a narrow belt crossing its southern portion from the western to the eastern boundary and then bending north and continuing to Bonaire, on the Georgia Southern and Florida Railway. The principal stone occurring is a soft, white, porous limestone, composed almost entirely of fossil Bryozoa, Orbitoides, Echinoids, and *Pecten perplanus,* named in the order of their importance. Other fossils also occur, but they are not so abundant. Some of the beds are glauconitic, but usually free from visible quartz grains. Overlying this bed, with frequently a thin clay parting, is a thin stratum of hard, white, partly or wholly crystalline limestone. The analyses of the various samples taken from the above limestones show an average calcium carbonate content of from 90 to 95 per cent.

The above mentioned soft limestone is contained in a 45-foot bed occurring at the base of the Jackson. This bed is in 1- to 15-foot layers of soft and slightly harder stone, with the soft predominating. The whole has a massive appearance, there being no distinct bedding planes. The strata seem to be in their original position and have no joints. The dip is about 8 feet per mile to the southeast, according to the exposures along the Ocmulgee River.

The limestone belt is characterized by a rugged topography with hills and ridges rising frequently 125 feet above the valleys. The limestone is exposed in bluffs and terraces along the lower slopes of the hillsides, with 40 to 50 feet of overlying yellow fullers earth, containing original and concretionary limestone layers. This clay is always yellow on the surface, due probably to weathering. It occupies the same stratigraphic position as the blue fullers earth mentioned in the description of the Deese property in Bleckley County. These beds are, in turn, overlain by residual, ferruginous sands, mottled, arenaceous clays and fossiliferous flint, derived from deposits of late Eocene or early Oligocene.

In the eastern edge of the county, east of Kathleen, the deeper valleys are below the horizon of the Jackson, while from the western border to within a few miles of the Ocmulgee River the creeks are within the horizon of the limestone.

Up to the present time practically no work has been done toward developing the limestones of the county with the exception of a small quarry on the Georgia Southern and Florida Railway near Tivola, from which a quantity of material has been quarried and used for road metal. This quarry, which is described on succeeding pages, has not been worked for several years. At a few localities the remains of old kilns may still be seen, where the stone was burned for building purposes before the advent of railroads. (See plate VII.) At other localities are small pits from which the material has been worked for local highway building.

The Georgia Southern and Florida and the Ocilla Southern railroads and the Ocmulgee River, all within a few miles of these deposits, offer means of transportation.

Railroad Cut, Bonaire (map locality H-1).—On the Georgia Southern and Florida Railway, one-fourth mile north of Bonaire, in the northeastern part of Houston County, there occurs an 8-foot exposure of soft, white, porous, highly fossiliferous limestone. The cut is through the western end of a low limestone ridge one-half mile in length. Near the eastern end of the ridge a well exposes 45 feet of limestone beneath an overburden of 3 feet. The ridge has an elevation of about 15 feet above the valley and a width at its base from 100 to 1000 feet, the greater width being near the western end. Scattered over the surface of the ridge are numerous fragments of cream colored limestone considerably harder than that exposed in the cut.

The above data indicate that there is present in this ridge a deposit of limestone about one-half mile long, 100 to 1000 feet wide (average 750 feet) and from 30 to 45 feet in thickness (average about 38 feet), with an overburden of from 3 to 5 feet. The correctness of these estimates can only be verified by prospecting.

The imperfect exposures made it impracticable to collect an average sample for analysis, however, the following analysis of a sample taken from the weathered exposure will give an idea of the character of the stone:

Analysis of Sample from G. S. & F. Railway Cut, One-fourth Mile North of Bonaire (Sample No. H-1)

Soda (Na_2O)	.04
Potash (K_2O)	.04
Lime (CaO)	52.00
Magnesia (MgO)	.00
Alumina (Al_2O_3) / Ferric oxide (Fe_2O_3)	1.62
Phosphorus pentoxide (P_2O_5)	.00

Silica (SiO_2) and insoluble	5.49
Undetermined	40.81
Total	100.00
Calcium carbonate ($CaCO_3$)	92.85

In working this deposit natural drainage can be secured by working the upper 12 feet of the limestone. If the workings are carried below the level of the valley the water must be removed by mechanical means. The nearness of the railroad to the deposit and the light overburden adds materially to its economic value.

Sasser Place (map locality H-2).—On the Sasser place, from one-half to 1½ miles west of Bonaire, a few scattered exposures of limestone were seen on the gentle slope at the foot of a high escarpment. These exposures occur in holes where trees were blown up, which holes give evidence of not more than 2 or 3 feet of overburden. No satisfactory data could be secured as to the extent and conditions of this deposit. The few exposures which occur over an area upward of 100 acres, together with the nearness to a railroad, indicate that the property is well worth prospecting.

DISTRICT BETWEEN THE G. S. & F. RWY. AND THE OCMULGEE RIVER, NORTH OF BIG INDIAN CREEK

This region is characterized by a comparatively rugged topography, consisting of a main plateau some 150 feet above the river, dissected by deep ravines along the creeks and branches. The limestone exposures occur along the lower edge of the escarpments, usually in the form of low ridges or terraces extending out from the main hillsides, and in creek bluffs and isolated knolls. The following is a generalized section of the eastern part of the county and also of Twiggs County.

Generalized Section, Houston and Twiggs Counties

	Feet
3. Residual red sands, mottled, arenaceous clays and fossiliferous flint	0-60

Jackson group.	
2. Cream colored (weathered) fullers earth containing thin layers of original and concretionary limestone	30-50
1. Massive, white, porous limestone composed almost entirely of fossils, with soft and harder layers varying from 1 to 15 feet in thickness. A 1- to 3-foot bed of hard, white, partly crystalline limestone occurs on top of the massive bed with frequently a 2-foot clay parting between it and the lower limestone bed...........................	40-50

Deposits 1 1/2 Miles East of Kathleen (map locality H-3).—Water-worn fragments of hard, white, partly crystalline, fossiliferous limestone, together with fragments of soft, white, highly fossiliferous limestone, cover the surface of three small knolls 1½ miles east of Kathleen. The tops of these small, rounded hills are 18 to 20 feet above the surrounding bottom land, each of which covers an area of from 2 to 3 acres.

No general sample could be secured from which the quality of the stone of these deposits could be accurately determined, but the weathered fragments seen show a very distinct similarity to the stone of the other deposits in this section. The fragments of stone, together with the tough black clay-soil covering the knolls, indicate a very high overburden. The deposits are admirably situated for development for local agricultural use.

Three Miles East of Kathleen (map locality H-4).—Fragments of soft, white, highly fossiliferous and hard, partly crystalline, fossiliferous limestone occur on the surface of a terrace-like projection at the base of a high escarpment, 1 mile south of Thompson Mill and 3 miles east of Kathleen. The top of this terrace is 20 feet above the floor of the valley and some 200 feet wide, extending from the public road, about 500 feet to the southeast, where it disappears beneath the main hillside. No exposures in place occur, but the loose fragments and black, tough clay-soil indicate a very light overburden.

Across the valley from this escarpment, one-fourth mile west, there is a similar terrace at the same elevation, but of less extent.

The surface of this terrace is likewise covered with limestone fragments and black soil with no exposures in place. The deposit over which the overburden is light is about 250 feet long, 100 feet wide and 20 feet thick, from the bottom land to the upper limit of the limestone fragments. The overburden is probably not more than 2 or 3 feet. Red sands and clays occur from the top of the limestone to the top of the main hill, 40 feet above. The fullers earth bed is apparently covered by this material.

A general sample could be obtained from neither of the above localities, but the limestone being exactly similar to that occurring at other points in this section of the country, it is quite probable that a sample would show approximately the same analysis. These deposits are well worth prospecting and it is probable that the information thus obtained would show the character and quality of stone to be of commercial value, at least for local agricultural purposes.

Geo. L. Small Property (map locality H-5).—Exposures of limestone and clay occur in the escarpments along a small branch running northward through lots 122, 123, 132 and 133, 11th district of Houston County, on the Geo. L. Small property, 4 miles east of Kathleen. An excellent exposure of the several beds occurs on the west side of the branch at a point one-half mile northwest of the Small residence. The following section, which is descriptive of the material of the individual beds, was observed at this locality.

Section on Geo. L. Small Place, 4 Miles East of Kathleen

	Feet
8. Residual red sands, mottled clays and flint to top of plateau	
Jackson group.	
7. Medium soft, cream colored, highly fossiliferous limestone. Weathers to soft, yellow, argillaceous material	15
6. Cream colored calcareous fullers earth free from grit. Conchoidal fracture.....................	16
5. Hard, white limestone.........................	2
4. Cream colored, calcareous fullers earth, containing small, clear quartz grains. Six layers of hard,	

white limestone from 4 to 6 inches thick, probably concretionary	28
3. White and red mottled clay	2
2. Hard, cream colored, fossiliferous, partly crystalline limestone	2
1. Soft, white, highly fossiliferous limestone. Fossils in lower part mainly Bryozoa, together with Pecten Periarchus and others. Upper 8 feet contains a greater variety of fossils	18
Branch bottom	0
	83

The sand and clay of bed 8 is the typical material occurring at the top of the higher hills and plateaus. Bed 7 can be correlated with no other exposure seen in this section. Examination of the fossils, however, may show its relationship to other outcrops. The strata from 1 to 6, inclusive, are without doubt the equivalent to the limestone and clay beds seen at numerous localities in Houston and Twiggs counties. At several exposures the original clay is blue and the weathered product cream colored. It is quite probable that below the zone of weathering the clay of this deposit is likewise blue.

Samples taken from the limestone strata show the following analyses:

Analyses of Samples from Geo. L. Small Place

Sample No.	22	24
Bed	7	1
Soda (Na_2O)	trace	.04
Potash (K_2O)	trace	.08
Lime (CaO)	42.92	53.60
Magnesia (MgO)	.03	trace
Alumina (Al_2O_3) / Ferric oxide (Fe_2O_3)	2.68	1.08
Phosphorus pentoxide (P_2O_5)	.08	trace
Silica (SiO_2) and insoluble	20.97	3.57
Undetermined	33.32	41.63
Total	100.00	100.00
Calcium carbonate ($CaCO_3$)	76.67	95.70

Sample No. 24 was taken one-fourth mile north of the point where the above section was noted.

Bed No. 1 of the section is the upper third of the limestone stratum which makes up the base of the Jackson group. The strata from No. 1 to No. 7, inclusive, belong to the Jackson group, while the age of No. 8 has not been determined, it is probably also Jackson. The strata occupy their original position, dipping slightly to the southeast. No joint planes are in evidence.

Beginning about 100 yards north of the point where the above section was observed and continuing to the river swamp five-eighths mile north, the lower limestone bed extends out from the main escarpments as a terrace or bench on both sides of the stream. Several ravines of varying widths cut through the limestone benches and back into the main escarpment. Good exposures of limestone occur along the sides and edges of the terraces while loose fragments cover the top. The tops of the benches vary from 100 to 500 feet in width, sloping gently towards the stream and are from 18 to 30 feet above the bottom land, the height reaching the maximum near the river swamp. The overburden is apparently from 1 to 3 feet in thickness over the deposits in the areas given.

Natural drainage may be had in a quarry in this deposit by keeping the floor slightly above the bottom land. The stone of the lower bed is an excellent material for agricultural purposes, but is unsuited for most other uses on account of its physical character as well as the impurities it carries.

The distance of the deposit from a railroad, 3½ miles, prevents its being a commercial proposition at present. It may, however, be worked for local use. The Ocmulgee River, 1 mile to the east, would possibly offer means of transportation.

Lot 66, 11th District (map locality H-6).—On lot 66, 11th district, 1½ miles southwest of the Small residence and 4 miles east-southeast of Kathleen, an excellent exposure of limestone in a bluff of an old stream escarpment shows the following section:

Section on Lot 66, 11th District, Houston County

	Feet
5. Red sands with flint to top of hill (float)	30
4. Hard, partly crystalline limestone	3
3. Covered (probably belonging to bed beneath)	7
2. Medium hard, thick bedded, highly fossiliferous, white limestone	10
1. Soft, massive bedded, cream colored, fossiliferous limestone; Bryozoa, *Pecten perplanus* and Periarchus	15
	65

A sample taken from the lower 25 feet shows the following analysis:

Analysis of Sample taken from Exposure on Lot 66, 11th District

(Sample No. 25)

Soda (Na_2O)	.12
Potash (K_2O)	.05
Lime (CaO)	53.48
Magnesia (MgO)	trace
Alumina (Al_2O_3) } Ferric oxide (Fe_2O_3) }	.80
Phosphorus pentoxide (P_2O_5)	.08
Silica (SiO_2) and insoluble	4.94
Undetermined	40.53
Total	100.00
Calcium carbonate ($CaCO_3$)	95.48

This steep bluff is some 250 yards in length with gentle slopes of the escarpment meeting it at either end. The overburden could not be determined definitely, but it seems to get heavier up the gentle slope from the face of the bluff to the top of the hill, a vertical height of 30 feet in a distance of 600 feet. The overburden on the edge of the bluff is practically nothing. Black clay-soil and surface tree roots indicate a light overburden for 100 feet back from the bluff.

This stone is of excellent quality for agricultural purposes, but owing to its distance from means of transportation it can probably be worked at present for local use only.

Roughton Place (map locality H-7).—On the Roughton place, 5 miles east of Kathleen, limestone exposures occur on the sides of a hill 1 mile west of the river and one-half mile north of the plantation quarters.

The stone is the usual soft, white, porous, highly fossiliferous limestone encountered throughout the county with hard, white, semi-crystalline limestone overlying. A general section is as follows:

Section on Roughton Place, 5 Miles East of Kathleen

	Feet
3. Black soil with water-worn boulders of hard, partly crystalline, white limestone	10
2. Alternating thin layers of soft, white, porous, highly fossiliferous limestone with a slightly harder stone of the same character. Lower 20 ft. massive, soft stone; some layers glauconitic. Bryozoa, *Pecten perplanus* and Periarchus in lower bed	35
1. Covered	20
Swamp	0
	65

A sample from bed No. 2 shows the following analysis:

Analysis of Sample from Roughton Place, 5 Miles East of Kathleen (Sample No. 20)

Soda (Na_2O)	.04
Potash (K_2O)	.12
Lime (CaO)	51.56
Magnesia (MgO)	trace
Alumina (Al_2O_3) / Ferric oxide (Fe_2O_3)	1.52
Phosphorus pentoxide (P_2O_5)	.03
Silica (SiO_2) and insoluble	7.02
Undetermined	39.71
Total	100.00
Calcium carbonate ($CaCO_3$)	92.06

The exposures of this limestone occur at frequent intervals on the north, east and west sides of a ridge extending northward from the main high plateau. The limestone hill has a maximum elevation of 65 feet above the creek swamp, on the north and east sides. The upper 10 feet of the hill consists apparently of black soil, while the lower 20 feet is covered so that the nature of the strata could not be determined. This leaves a thickness of 35 feet of limestone. It is probable, however, that the limestone extends beneath the lowest exposure seen and also above the highest.

The foregoing data, together with the dimensions of the ridge indicate a body of limestone 1600 feet long, 900 feet wide and 35 feet thick with a maximum overburden of 10 feet, and an average of 5 feet. Prospecting is necessary to verify the foregoing estimates.

The lowest exposure of limestone is 20 feet above the creek swamp and about 40 feet above the river at low water. This elevation is probably sufficient to secure a quarry from being flooded during seasons of high water. It also would afford natural drainage to the workings.

The Southern Railway is 2 miles east of these exposures, on the opposite side of the Ocmulgee River, and the Georgia Southern & Florida Railway is 5 miles west. The Ocmulgee River, however, is less than 1 mile east and is navigable the entire year for small crafts.

Across a shallow valley to the east of the limestone ridge, that part of the main escarpment in the horizon of the limestone bed has a gentle slope to the creek swamp. This slope is about 10 in 100 feet and continues along the edge of the hill for about one-half mile. No exposures of the limestone occur, but fragments and boulders are scattered over the surface.

SOUTH OF TIVOLA

From 1 to 4 miles south of Tivola the Georgia Southern & Florida Railway runs parallel to and one-half mile west of the main escarpment of Limestone Creek. Extending westward from this escarpment are several limestone ridges or spurs which have a height of 20 to 35 feet above the level of the railroad and a width of 100 to 1000 feet at the base. The natural outcrops consist of loose boulders and fragments of limestone scattered over the surface of the spurs. However, 2 quarries and the railroad cuts offer excellent exposures of the strata. The deposits consist of alternating beds of hard and soft, white stone, the latter predominating, composed almost entirely of Bryozoa and other fossils. Some of the beds are slightly glauconitic. Chemical analyses show 90 to 95 per cent calcium carbonate. The material of these deposits belongs to the lower part of the Jackson group and is similar to the material of the other limestone exposures in the county. The maximum exposed thickness of the limestone here is 45 feet, which is probably the entire limestone bed occurring at the base of the formation. Overlying the deposit in the ridges is a foot or two of soil. As the foot of the main hillside is approached the overburden gets much heavier, consisting of cream colored fullers earth. Overlying the clay and capping the ridge are sand, clay and flint.

The western end of most of the ridges is within a few feet of the railroad, which offers excellent means for transportation. The base of the limestone bed is at about the drainage level, which means that the larger portion of the deposit could be worked with natural drainage.

The physical and chemical properties of the stone make it best suited for agricultural purposes. It is too soft for road work, concrete or other similar uses.

G. S. & F. Quarry (map locality H-8).—The G. S. & F. limestone quarry is located a few hundred yards east of the Georgia Southern & Florida Railway, 2 miles south of Tivola. The materials exposed here in the vertical face of the quarry are soft and hard limestones described in the following section:

Section of G. S. & F. Quarry, 2 Miles South of Tivola

	Feet
7. Red, sandy soil (overburden)	1-2
6. Hard, white, partly crystalline limestone	1½

5. Soft, light cream colored to white, porous limestone composed almost entirely of fossils, Bryozoa, Pecten, etc.	10
4. Medium hard, white, highly fossiliferous, porous limestone	½
3. Similar to bed 5	4
2. Similar to bed 4	1
1. Similar to beds 3 and 5	12
Floor of quarry	0
	30

In a well nearby limestone is continuously exposed to 15 feet below the quarry floor. A sample of this material could not be obtained, but from the surface it appears to be similar to the lower bed at the quarry. Samples taken from the different beds in the quarry face show the following analyses:

Analyses of Samples 2 Miles South of Tivola

Sample No.	4	5	6	7
Bed No.	1	3	5	All beds
Soda (Na_2O)	.12	.18	.22	.14
Potash (K_2O)	.16	.32	.38	.22
Lime (CaO)	53.02	51.12	52.98	50.90
Magnesia (MgO)	.25	.15	.22	.40
Alumina (Al_2O_3) Ferric oxide (Fe_2O_3)	.83	.94	1.00	1.16
Phosphorus pentoxide (P_2O_5)	.05	.06	.10	.10
Silica (SiO_2) and insoluble	4.22	5.68	2.84	6.05
Undetermined	41.35	41.55	42.26	41.03
Total	100.00	100.00	100.00	100.00
Calcium carbonate ($CaCO_3$)	94.67	91.30	94.60	92.40
Magnesium carbonate ($MgCO_3$)	.53	.33	.44	.85
Combined carbonates	95.20	91.63	95.04	93.25

The limestone bed here exposed is at the base of the Jackson group. The stone is equivalent to and similar in every respect to the various other limestone exposures seen throughout the county. As shown in the section the entire bed is made up of alternating soft and harder layers. There is, however, no sharp line of contact between the different beds, but a gradual gradation from one to the other. The dip of the beds is so slight as not to be noticeable. They are apparently in their original position with a dip of about 10 feet per mile to the south-southeast. No joint planes have been developed.

The deposit at this locality forms two low limestone ridges extending west and northwest respectively, from the base of a main high escarpment. The southernmost ridge extends eastward about 1000 feet from the G. S. & F. quarry, to the point where the overburden gets excessive. This spur has a width of from 200 to 400 feet at the base with a maximum limestone thickness above the floor of the quarry of 30 feet. The ridge slopes off gradually on both sides to about the level of the base of the quarry face. The overburden varies from 2 feet at the western end to 10 feet some 1000 feet east. The average is probably in the neighborhood of 5 feet.

Joining this ridge about 750 feet east of the quarry and running northwest to the Georgia Southern & Florida Railway is another limestone ridge of somewhat larger proportions. Near the railroad a few exposures of limestone occur from the base to within a few feet of the top while loose fragments cover the slopes. The top of this spur is about 35 feet above the swamp to the south or 30 feet above the floor of the above mentioned quarry. No definite idea as to the thickness of the overburden could be obtained, but the above elevations and the exposures seen indicate a thickness of 0 to 10 feet. A small area on the center of the ridge has an elevation of about 50 feet above the swamp, which indicates that the overburden on that area is heavy. This deposit is three-eighths mile in length and varies from 200 to 1000 feet in width.

The floor of the present quarry is about 5 feet above the swamp to the northeast and therefore has natural drainage. Several feet more may be worked and still retain drainage by the use of a series of ditches. It is possible that the entire 45-foot thickness could be worked with only a small quantity of water having to be removed.

The above figures given are more or less rough estimates, but will serve to give a general idea of the quantity of limestone available.

The quarry on this property has not been operated for several years and hence no data on the methods of working could be secured other than those indicated by the plant and equipment, which are still intact. The quarry wall or face has a maximum height of 30 feet in the center, while at the ends the minimum, 8 feet, is reached. The face is 200 feet long and 100 feet back from the beginning of the working.

The power plant consists of a 60-horsepower fire-tube boiler and a 40-horsepower slide-valve engine. The engine is connected to a shaft by a belt which drives a No. 6 Gates crusher. The drums which pulled the loaded cars from the quarry to the crusher platform are connected to the crusher shaft. A bucket elevator lifted the crushed stone from the crusher discharge into railroad cars, which stood on a siding near the crusher. The elevator was also driven from the crusher shaft.

The limestone was probably drilled with hand steel from the top and shot down by means of black powder or dynamite. The broken material was then loaded by hand into the cars, the larger lumps being first broken to convenient size.

The stone thus quarried and worked was used in Macon as a road surfacing material with indifferent success. The packed limestone has a rather high cementing power and while damp is very serviceable. When dry, however, the stone crushes to a powder very easily and is carried away by the slightest air currents.

South of Tivola, 2 1/2 to 3 1/2 Miles (map locality H-9).—Near the Georgia Southern & Florida Railway, 2½ miles south of Tivola, an exposure of soft, white, highly fossiliferous, porous limestone occurs in an old pit 50 feet east of the road bed. The exposed strata have a thickness of 8 feet and appear to be in the horizon of beds 3, 4 and 5 of the section of the G. S. & F. quarry, 2 miles south of Tivola. East of the pit, fragments of soft limestone occur over the hillslope to an elevation of 14 feet above the floor of the pit and the valley with cream colored clay above. This indicates that the upper 14 feet of the limestone is above the bottom of the pit with the lower 31 feet of the 45-foot bed below.

These exposures are on the western end of a low, narrow, limestone ridge. The overburden ranges from less than 1 foot at the western end of the ridge to 10 feet one-fourth mile east. East of this latter point the overburden increases rapidly until the top of the main escarpment is reached. The base of the ridge has a width of from 100 to 400 feet, while the top is from 14 to 25 feet above the valley on either side.

No information could be obtained as to what use the limestone from the pit was put, probably, however, for ballast. The pit has not been worked for a number of years.

Three Miles South of Tivola (map locality H-9).—Loose fragments and boulders of soft, white, highly fossiliferous, porous limestone cover the western end of a low limestone ridge 3 miles south of Tivola. The upper limit of the limestone is 12 feet above the surrounding valley with clay occurring above. If the limestone bed here has its usual thickness of about 45 feet then the greater thickness occurs below the base of the ridge.

The overburden on the western end of the ridge, 100 feet east of the Georgia Southern & Florida Railway, is less than one foot. East from this point the overburden gets gradually heavier until it reaches a thickness of about 10 feet one-fourth mile from the railroad. Farther east the hillslope is much steeper and the overburden gets correspondingly heavier. The top of the limestone ridge is from 12 to 22 feet above the valley, while the base is from 100 to 500 feet wide.

The dimensions of the two foregoing deposits were estimated and are only intended to give an idea of the extent of the limestone body.

Three and One-fourth Miles South of Tivola (map locality H-9).—A railroad cut on the Georgia Southern & Florida Railway, $3\frac{1}{4}$ miles south of Tivola exposes the following section:

Section on G. S. & F. Railway, 3 1/4 Miles South of Tivola

	Feet
4. Soil (thickness increases rapidly to top of escarpment)	
3. Soft, white, fossiliferous, porous limestone.........	6
2. Cream colored fullers earth, partly covered........	8
1. Soft, white, highly fossiliferous, porous limestone..	4
Floor of cut..................................	0
	18

This exposure is 1½ miles southwest, approximately on the line of strike of the Jackson strata, of the Georgia Southern & Florida Railway quarry described on preceding pages. Then the equivalent beds of the two sections should be found at about the same elevations. The marked difference between the two sections may be explained as follows:

The floor of the railroad cut is about 25 feet above the floor of the quarry which indicates that the lower 4 feet in the cut is equivalent to the upper part of bed 5 at the quarry; bed No. 6 at the quarry is either absent in the above section or is covered by talus; bed No. 2 at the railroad cut is equivalent to the cream colored clay occurring as overburden east of the quarry; while bed No. 3 of the above section is either absent in the vicinity of the quarry or covered.

(Map locality H-10).—In the eastern edge of Houston County, one-fourth mile south of Big Indian Creek, 12 miles north of Hawkinsville, water-worn boulders of soft, white, highly fossiliferous, porous limestone cover the surface of a small knoll. This knoll covers about 1 acre and has a maximum height of 12 feet above the creek bottom. No exposures of the stone in place occur, but the quantity of loose material indicates little or no overburden.

It is probable that close investigation would reveal other deposits between this point and the G. S. & F. quarry, several miles to the west.

SOUTH OF PERRY

The limestone belt south of Perry is characterized by several ridges rising about 100 feet above the creek and running east and west for from 2 to 10 miles. These ridges are the escarpments on the south sides of Flat Creek and its tributaries. Moss Hill and Ross Hill are the most notable examples of these ridges. The geologic section here is quite similar to that of the eastern part of the county and the limestone exposures are of the same type and in the same position, namely, along the base of the ridges and extending out into the bottoms as low spurs and benches and as isolated knolls. The lower limestone bed is overlain by a thick bed of clay, with thin limestone layers, which is, in turn, overlain by red sands, mottled, arenaceous clays and flint.

Duncan Property (map locality H-11).—Three deposits of limestone occur on the C. C. Duncan property, 2½ miles south of Perry, Houston County, on the south side of the Ocilla Southern Railroad. These deposits occur in three low ridges which extend northward from the eastern end of Ross Hill. The stone is exposed mainly as float, but a few exposures in place were noted. The stone is a soft, friable cream colored limestone composed almost entirely of Bryozoa with an occasional *Pecten perplanus* and Periarchus. On account of the highly weathered condition of the visible stone no sample for analysis was taken. However, an average of the analyses of samples secured in the southern portion of Houston County from the same bed of limestone is as follows:

Average of Analyses of Limestone Samples from Southern Portion of Houston County

Soda (Na_2O)	.05
Potash (K_2O)	.07
Lime (CaO)	53.00
Magnesia (MgO)	.14
Alumina (Al_2O_3) / Ferric oxide (Fe_2O_3)	.95
Phosphorus pentoxide (P_2O_5)	.07
Silica (SiO_2) and insoluble	3.16
Undetermined	42.56
Total	100.00
Calcium carbonate ($CaCO_3$)	94.75

The analyses from which this average analysis was taken contain from 92 to 98 per cent calcium carbonate.

The limestone of these deposits belongs to the Jackson group. The type of stone and the overlying fullers earth indicate that it is the upper portion of the limestone bed at the base of the group. At the Tivola quarry, 6 miles northeast of this point the bed is about 45 feet thick. It is probable that about the same thickness also occurs at this point. Following the top of the limestone deposits towards Ross Hill, fullers earth is seen to overlie the stone. The limestone is apparently in its original position, dipping slightly to the southeast.

As mentioned above, the limestone deposits are three in number and occur in low spurs which extend northward from the main ridge, Ross Hill. The largest of the three is the easternmost, the top of which is 12 or 13 feet above the bottom land. The exposures and float cover a stratigraphic thickness of 10 feet with 2 to 3 feet of black, clayey soil overburden. The base of the ridge covers approximately 5 acres. The two spurs to the westward have about the same vertical dimensions and cover together about 2 acres.

These deposits can be worked to the level of the bottom land without the interference of water. If, however, a larger quantity of stone is desired it could be worked below the drainage level with only a small quantity of water having to be handled. There is probably no danger of the workings being overflowed since the nearest creek is a half mile or more away. The Ocilla Southern Railroad is within 100 yards of all of these deposits.

To summarize, there are on this property three deposits of limestone within a few hundred feet of each other, covering a total area of about 7 acres. The maximum thickness of stone above the drainage level is 10 feet with an average of probably 1 foot less. The actual thickness of the limestone is probably near 45 feet. The overburden to be removed will scarcely exceed 3 feet for the area given.

These figures are merely estimates and are only intended to give an idea of the extent of the limestone body. Prospect pits and holes are necessary to obtain more definite information.

The foregoing analysis shows a comparatively pure limestone which is well suited for agricultural purposes. The stone has not sufficient strength and toughness for road metal, concrete work or such uses. It will make a low-grade lime upon being calcined or burned.

Berry Place (map locality H-12).—On the Berry place, one-half mile south of Duncan Station, on the Ocilla Southern Railroad, small exposures and fragments of limestone occur along the bases of a series of low hills. The stone in place is the same soft material described in the other localities of the county, while the loose boulders are of the hard, partly crystalline variety. The upper limit of the limestone is some 10 feet above the valley, while clay occurs from this point to the top of the hills, 15 feet higher. This latter material is similar and probably equivalent to that of bed 4 of the section of Ross Hill. Evidently, then, the limestone continues below the floor of the valley for a thickness of 25 to 35 feet.

The maximum overburden is 15 feet, but the gently sloping sides and the limestone bed extending out as terraces bring the average to a much lower figure. Prospecting is necessary to give an accurate idea of the actual extent of the deposit and the overburden.

The weathered condition of the exposures prevented the securing of an average sample. It is safe to say, however, that an analysis would show approximately the same calcium carbonate content as the various samples obtained from other localities in the county.

One-fourth to One-half Mile East of Perry-Elko Road (map locality H-13).—Between one-fourth and one-half miles east of the Perry-Elko public highway these limestone and clay ridges extend northward from the foot of Ross Hill. The lower 10 feet of the hillsides is covered with fragments of limestone of the two varieties described in the foregoing localities, while the upper 6 or 8 feet consists of the yellow clay of the middle beds exposed on Ross Hill. This indicates that the greater thickness of limestone extends below the level of the valley. The eastern deposit covers some 10 acres while the other two cover 3 or 4 acres each. The maximum overburden of 8 feet occurs along the center of the ridges, but the gently sloping sides bring the average to a lower figure. No exposures in place occur.

Between the ridges and on either side, other low hills occur with no limestone visible. It is quite probable, however, that prospecting would prove up other deposits quite as extensive and with light overburden.

The bases of these deposits are some 30 feet above the creek, which is enough to protect workings during flood seasons. Duncan Station on the Ocilla Southern Railroad is 1 mile to the east.

Ross Hill (map locality H-13).—Soft, friable, cream colored limestone is exposed on the property of W. A. Strouther, on the northern slope of Ross Hill along the Perry-Elko public road, 3½ miles south of Perry. This stone is composed almost entirely of Bryozoa with an occasional *Pecten perplanus* and Periarchus. The following section is descriptive of all strata exposed:

Section on North Slope of Ross Hill

	Feet
Late Eocene (residual).	
5. Red, sandy, clayey soil, containing fragments and boulders of fossiliferous flint. Continuous to top of ridge	40
Jackson group.	
4. Cream colored fullers earth, containing thin, hard, limestone layers	8
3. Hard, partly crystalline limestone with medium hard, highly fossiliferous layers beneath	2.5
2. Cream colored fullers earth	3.5
1. Soft, highly fossiliferous limestone, similar to that seen throughout Houston County. Harder stratum at top of bed	18
Bottom land	0
	72

A sample secured from the upper 10 feet of bed 1 of the section shows the following analysis:

Analysis Limestone from Ross Hill

(Sample No. 1)

Soda (Na_2O)	trace
Potash (K_2O)	trace
Lime (CaO)	53.18
Magnesia (MgO)	trace
Alumina (Al_2O_3), Ferric oxide (Fe_2O_3)	1.20
Phosphorus pentoxide (P_2O_5)	.04
Silica (SiO_2) and insoluble	4.23
Undetermined	41.35
Total	100.00
Calcium carbonate ($CaCO_3$)	94.98

The material of this stone insoluble in hydrochloric acid consists of small clear quartz grains, glauconitic Bryozoa stems and sponge-like masses and concretions of glauconite.

The limestone and fullers earth exposures on this property belong to the Jackson group of Tertiary age. The limestone exposed at the foot of the hill is the upper part of the limestone bed at the base of the group. Seven miles northeast of this point the bed is 45 feet thick and 12 miles southwest it is at least 35 feet thick, hence the bed here is likely to be over 40 feet in thickness. The strata seem to occupy their original position, dipping slightly to the southeast.

This limestone deposit occurs at the gently sloping foot of Ross Hill. The outcrop has a width of about 30 feet and a stratigraphic thickness of 18 feet above the base of the exposure. The average being probably one-half as great. This profile continues for about one-fourth mile west of the road. The stone is exposed along the road-side and in a pit a few feet west of the highway. The overburden is probably 2 or more feet thick over the gentle slope.

About one-fourth mile west of the road there are two low lime-stone ridges covering 2 and 5 acres respectively. The top of the ridges are about 12 feet above the bottom land. These limestone deposits are probably in the upper part of bed 1 of the section. The overburden is likely not over a foot or two thick. No exposures occur in place, except in a shallow ditch on the larger deposit. Water-worn limestone fragments cover both the hills.

These three deposits may be worked for a thickness of 12 to 18 feet above the drainage level, and for a probable total thickness of 40 feet. The Ocilla Southern Railroad is about 1½ miles east of the Perry-Elko road where the limestone deposit occurs.

The foregoing analysis shows a good grade of limestone admirably suited for agricultural purposes. The stone is too soft for road or concrete work, although it has been used for the former purpose. Upon burning or calcining the stone a low-grade lime will result.

Mossy Ridge (map locality H-14).—Near the foot of Mossy Ridge, an exposure of 6 feet of limestone occurs in a pit on the east side of the National Highway, 5 miles south of Perry. The stone is in alternating beds of soft, white, highly fossiliferous limestone, about 1 foot thick, and a stone of the same general character, but somewhat harder. The outcrop seems to be in the horizon of bed No. 3 of the section noted on Ross Hill, 3 miles to the east. This being true, there is, then, 3 feet of clay between the bottom of the pit and the main limestone bed, provided, of course, that the series is the same as in Ross Hill.

Supposing the lower limestone bed to have the same thickness here as in the eastern part of the county, there is, below the quarry floor, a deposit of stone about 45 feet thick.

This pit is near the bottom of the gentle slope at the foot of the ridge, and has an overburden of 1 foot. On both sides of the road there is an area of about 75 acres at a maximum elevation of the top of the pit and sloping gently from this height to the meadow land, about 10 feet below. No data could be secured as to the thickness of the overburden on the limestone under this area, but the evidence furnished by the black clay-soil and surface tree roots indicates only a very few feet. Prospecting is necessary to gain a definite idea of the extent of the deposit.

Indian Cave (map locality H-15).—At Indian Cave, one-half mile north of the Davis house, 7 miles southwest of Perry on the lower Montezuma road, soft, white, fossiliferous limestone 6 feet thick is exposed. Immediately over the exposure and covering a small field to the south, is 1 to 5 feet of cream colored fullers earth and soil.

A sample of the limestone shows the following analysis:

Analysis of Sample from Indian Cave
(Sample No. 26)

Soda (Na_2O)	trace
Potash (K_2O)	trace
Lime (CaO)	54.60
Magnesia (MgO)	trace
Alumina (Al_2O_3) / Ferric oxide (Fe_2O_3)	.60
Phosphorus pentoxide (P_2O_5)	.06
Silica (SiO_2) and insoluble	2.21
Undetermined	42.53
Total	100.00
Calcium carbonate ($CaCO_3$)	97.60

The residue, insoluble in hydrochloric acid, shows clear quartz grains about .25 mm. in diameter, siliceous sponge-like casts or replacements, glauconitic concretions, and Bryozoa casts.

The clay occurring over the stone indicates that the visible deposit belongs to the upper part of the 45-foot limestone bed. Prospecting is necessary to determine the extent of the deposit.

PULASKI COUNTY

The limestone exposures of Pulaski County are confined to the escarpments and banks of the Ocmulgee River and its tributary streams in the immediate vicinity of the river. Several types of stone occur in the outcrops which are described under locality descriptions below. This stone belongs to the Jackson group and the lower Oligocene. The latter is also represented by residual fossiliferous flint and mottled clayey sands which cover practically the entire county.

The topography of Pulaski County varies from flat to rolling in the southern portion to hilly along the northern border. These hills frequently rise 100 or more feet above the stream beds. Flint and the residual argillaceous sand cap the uplands while the limestone of the Jackson group outcrops along the foot of the slopes.

Bluff 5 1/2 Miles Above Hawkinsville (map locality P-1).—An exposure of soft, white, argillaceous, chalky limestone occurs in a bluff on the west bank of the Ocmulgee River, 5½ miles above Hawkinsville. The stone is at the same horizon and lithologically similar to the massive bed at Colliers Bluff and the upper massive limestone bed in Taylors Bluff, hereafter to be described.

This exposure occurs 40 feet above the river in a steep escarpment which attains a height of 70 feet above the water. Only a few square feet of the stone is visible and hence the position of the outcrop in the stratum could not be determined. The bluff is capped with red sand and flint, while talus and drift cover the steep side of the bluff below the outcrop. The escarpment has a river frontage of about 250 feet.

No definite idea could be obtained as to the actual overburden on the limestone, it, however, appears to be about 30 feet, but may be considerably less. Prospecting is necessary to determine the workability of this deposit. Since the exposure was so limited no sample for analysis was taken. The analysis of the sample taken from Colliers Bluff, 1 mile down-stream, will serve to give a fair idea of the chemical character of this stone.

Colliers Bluff (map locality P-2).—Limestone outcrops in Colliers Bluff, 4½ miles north of Hawkinsville on the west side of the

Ocmulgee River. The following section was here observed:

Section at Colliers Bluff, West Bank Ocmulgee River

	Feet
Residual Eocene or Oligocene.	
5. Red ferruginous sands and flint	18
Jackson group.	
4. Soft, white, argillaceous, chalky limestone; Bryozoa and Pecten rare	22
3. Soft, greenish, highly fossiliferous, glauconitic, arenaceous limestone	3½
2. Soft, bluish, fossiliferous limestone	1
1. Covered	15½
River	0
	60

Beds 2, 3, and 4 of this section are at the same horizon and equivalent to beds 9, 10, and 11 of Taylors Bluff, 2 miles south.

A sample taken from bed 4 shows the following analysis:

Analysis of Limestone Sample from Colliers Bluff, 4 1/2 Miles North of Hawkinsville, West Bank Ocmulgee River (Sample No. 13)

Soda (Na_2O)	.38
Potash (K_2O)	.08
Lime (CaO)	46.76
Magnesia (MgO)	trace
Alumina (Al_2O_3) } Ferric oxide (Fe_2O_3) }	2.06
Phosphorus pentoxide (P_2O_5)	.08
Silica (SiO_2) and insoluble	11.20
Undetermined	39.44
Total	100.00
Calcium carbonate	83.60

The limestone strata exposed in this bluff belong to the Jackson group. The beds appear to be dipping 8 to 10 feet per mile to the southeast. The exposures, however, are not sufficiently extensive to determine this accurately. No joint planes have been developed.

Colliers Bluff has a frontage along the river of about one-fourth mile, with the limestone exposures occurring at intervals from the center to the up-stream end. A maximum thickness of 26 feet of limestone is visible, covered by apparently 18 feet of clayey sands.

It is quite possible that the upper limit of limestone is at a much higher level.

The base of the upper massive bed is 20 feet above the usual low-water mark. A quarry floor at this level would probably not be flooded except in seasons of extreme high water. The comparatively low calcium carbonate content of the stone together with the apparently heavy overburden and distance from railway transportation makes it of doubtful economic value, except for local agricultural uses, for which purpose quite a quantity of stone could be obtained along the edge of the bluff with the removal of very little overburden. The limestone is suitable also for the manufacture of hydraulic lime.

Taylors Bluff (map locality P-3).—Excellent exposures of strata of the Jackson group occur over a stratigraphic thickness of 50 feet in Taylors Bluff, 3½ miles above Hawkinsville on the east bank of Ocmulgee River on the property of J. B. Hardin of Atlanta. The following section is exposed:

Section Taylors Bluff, Ocmulgee River

	Feet
Residual Eocene or Oligocene.	
12. Drift and overburden red, sandy loam and gray loam	35
Jackson group.	
11. Soft, white, argillaceous, chalky, massive limestone; fossils rare, shark's teeth	25
10. Soft, greenish, arenaceous, highly fossiliferous, glauconitic limestone	3½
9. Soft, blue, fossiliferous, argillaceous limestone or marl	1½
8. Soft, white, fossiliferous limestone with hard masses	2½
7. Calcareous, arenaceous clay; weathers white, originally blue	2
6. Hard, gray, calcareous sandstone, fossils and glauconite	2
5. Soft, white, calcareous, fossiliferous sandstone	2½
4. Hard, gray, calcareous sandstone, fossils and glauconite	4
3. Blue, arenaceous clay	3
2. Hard, gray, calcareous sandstone, fossils and glauconite	½
1. Blue, arenaceous clay	1½
	83

Samples for analysis taken from the strata of the above section show the following chemical compositions:

Analyses of Samples from Taylors Bluff

Sample No.	9	10	11	12
Bed No.	11	10	9 & 8	6 & 4
Soda (Na_2O)	trace	.12	.10	.20
Potash (K_2O)	trace	.12	.20	.14
Lime (CaO)	49.56	41.56	36.40	23.64
Magnesia (MgO)	.15	.20	.18	.20
Alumina (Al_2O_3) / Ferric oxide (Fe_2O_3)	2.66	6.56	2.08	1.56
Phosphorus pentoxide (P_2O_5)	.11	.36	.15	.09
Silica (SiO_2) and insoluble	9.25	20.45	33.75	54.02
Undetermined	38.27	30.63	27.14	20.15
Total	100.00	100.00	100.00	100.00
Calcium carbonate ($CaCO_3$)	88.26	74.26	65.00	42.24
Magnesium carbonate ($MgCO_3$)	.32	.42	.38	.42
Total carbonates	88.58	74.68	65.38	42.66

The limestone strata exposed in Taylors Bluff probably belong to the Jackson group of Tertiary (Eocene) age while the overlying argillaceous sands are probably residual Lower Oligocene deposits. The dip is between 10 and 15 feet per mile to the south-southeast. No joint planes seem to have been developed.

Taylors Bluff extends along the east side of the Ocmulgee River for a distance of about 1500 feet. Jordan Creek is a short distance below the lower end. For the first 500 feet going up-stream there are no exposures of limestone, while from this point to the up-stream end of the bluff the exposures are practically continuous. The face of the escarpment is steep its entire length, varying from a 40 per cent slope near the lower end to a practically vertical face at its upper end. The apparent thickness of overburden varies from 30 to 40 feet, which is too great to allow profitable exploitation. Along the down-stream end of the bluff considerable quantities of the stone could be worked along the face of the exposure with the removal of very little overburden. After working from 10 to 30 feet back into the escarpment the overburden will get too heavy to allow profitable operation. The stone that could be worked here is the upper soft massive bed as given in the above section.

The analysis shows a limestone of medium grade. It is well suited for agricultural uses and would make a low-grade hydraulic lime. This stone is of greatest value for local agricultural purposes. The comparatively small quantity under light overburden, together with its low calcium carbonate content, prevent its being of any very great commercial value. If the quantity of workable stone is greater than apparent, it will be practicable to work and ship the stone by river.

Dickey Place (map locality P-4).—Good exposures of limestone occur in 3 small quarries on the J. B. Hardin property, known as the "Dickey Place," 3½ miles north of Hawkinsville on the Upper River road, land lot 351, 21st district. The stone exposed is soft, cream colored, argillaceous limestone similar in every respect to the upper massive bed at Taylors Bluff, 1 mile west. A sample of the stone taken from a vertical line in the face of one of the old workings shows the following chemical analysis:

Analysis of Limestone Sample from Dickey Place

Soda (Na_2O)	trace
Potash (K_2O)	trace
Lime (CaO)	51.48
Magnesia (MgO)	.18
Alumina (Al_2O_3) / Ferric oxide (Fe_2O_3)	2.04
Phosphorus pentoxide (P_2O_5)	.24
Silica (SiO_2) and insoluble	6.65
Undetermined	39.41
Total	100.00
Calcium carbonate ($CaCO_3$)	91.18

The limestone of this deposit probably belongs to the Jackson group. Immediately overlying the limestone is mottled argillaceous sand with thin flint layers apparently in place. These materials are probably residual Lower Oligocene.

The exposures of limestone on this property occur in three small quarries along the base of a gently sloping creek escarpment. The largest is 30 feet wide and worked 20 feet back into the hill with a maximum vertical face of 12 feet. The other two are of smaller dimensions except the face which is the same height. The first mentioned is about 50 feet and the other two 100 and 150 feet east of the Upper River road. There is an area of about one-half acre directly northwest of the line of the quarries over which the overburden is not more than 2 feet. A maximum thickness of 12 feet of limestone lies above drainage level.

Continuing northeastward along the escarpment the slope is about the same as on the road, no exposures of limestone occur, therefore the overburden could not be determined. The same is the case across the road west of the deposit. It is probable that the overburden is light over both of these areas up to an elevation of 12 feet above the drainage level.

This stone was quarried and burned for building lime, in the excavation from which it was taken. The quality of the stone was such, however, that a low-grade lime resulted. The stone is best suited for agricultural uses. The small quantity of stone in sight and the distance from the nearest railroad, 2½ miles, makes the deposit of questionable value other than for local use.

Ocmulgee River near Hawkinsville (map locality P-5).—Limestone probably of Lower Oligocene age is continuously exposed on the west side of the Ocmulgee River from Hawkinsville to 2 miles below. These exposures are in vertical bluffs at the base of which the river flows. None of the exposures are of economic importance, because of the overburden which varies from 10 to 20 feet.

In the river bluff at the cotton mill, a short distance below the Hawkinsville wagon bridge, 25 feet of soft, white, argillaceous limestone similar to the upper bed at Taylors Bluff is exposed with an overburden of 10 feet of sand. It is probable that the overburden is somewhat less over this deposit, but even then the value of the property is too great to allow the quarrying of the limestone, as it is located in the business section of Hawkinsville.

One-half mile down-stream from this deposit there is a limestone exposure 15 feet thick underlying 10 to 15 feet of sand and clay. The upper portion of this exposure is soft and very highly fossiliferous. The limestone strata are dipping down-stream at such a rate that the top of the limestone bluff at the cotton mill should be about 10 feet above the water at this point.

Two hundred feet further down-stream the fossiliferous limestone material mentioned in the preceding paragraph is only 18 inches above the surface of the water and is overlain by 22 alternating layers of hard, white limestone and calcareous fullers earth. The clay layers are from 1 to 8 inches thick and the limestone 4 to 20 inches thick. Ten to 12 feet of Pleistocene sands overlie the section. The dip of the strata is 8° south, while a short distance down-stream the strata are tilted slightly northwestward, indicating a slight local disturbance, probably due to the caving in of the roof of a large underground cavern.

Exposures along the water's edge continue down-stream for a mile or more.

DOOLY COUNTY

Although the entire western half of Dooly County, with the exception of a narrow strip along the Flint River, is within the Eocene (Jackson) and Oligocene terranes, both of which contain limestones, no natural exposures, however, of the stone were seen in place. The Oligocene deposits which cover the eastern and greater portion of this area consist of residual red and mottled argillaceous sands and arenaceous clays and fossiliferous flint. This last named material has originated from silicification of the limestone. The Jackson group occupies a narrow strip along Hog Crawl Creek, the northwestern boundary of the county, and also a strip along the escarpment of the Flint River. The channels and escarpments of Lampkins and Pennehatchie creeks for several miles east of the river are likewise within the horizon of the Jackson group of formations.

With a few exceptions this group is covered throughout these areas by float from the overlying Oligocene and by stream deposit material. The only natural exposures seen are along Pennehatchie Creek, 1½ miles southeast of Lilly, which are described under map locality D-3 on page 114.

L. Frieden Place, 9 Miles East of Montezuma (map locality D-1). —In the extreme northeastern part of the county on the L. Frieden property, a well was being dug near Hog Crawl Creek at the time of the writer's visit. It was being curbed as sunk and hence the strata cut could not be seen. Mr. Frieden, however, furnished the following section which was verified by the excavated material:

Section in Well on L. Frieden Place, Hog Crawl Creek

	Feet
Oligocene (residual).	
4. Red, argillaceous sand	8
Jackson group.	
3. Cream colored fullers earth	17
2. Medium hard, highly fossiliferous, glauconitic limestone	5
1. Soft, white limestone, composed of Bryozoa with scattered *Pecten perplanus* and Periarchus	15
	45

The fullers earth and limestone belong to the Jackson group and are equivalent to the exposures of the same materials in Houston, Twiggs and Bleckley counties.

A sample taken from the pile of excavated limestone shows the following chemical composition:

Analysis of Limestone Sample from Well on L. Frieden Place (Sample No. 28)

Soda (Na_2O)	.06
Potash (K_2O)	.05
Lime (CaO)	53.20

A. LIMESTONE RIDGE ON SMALL PROPERTY, 4½ MILES EAST OF KATHLEEN, HOUSTON COUNTY.

B. LIMESTONE QUARRY AND KILN ON HARDIN PROPERTY, 3½ MILES NORTH OF HAWKINSVILLE, PULASKI COUNTY.

Magnesia (MgO)	.04
Alumina (Al_2O_3) / Ferric oxide (Fe_2O_3)	2.68
Phosphorus pentoxide (P_2O_5)	trace
Silica (SiO_2) and insoluble	4.27
Undetermined	39.70
Total	100.00
Calcium carbonate ($CaCO_3$)	95.00

The well is in the top of a hill 300 yards east of Hog Crawl Creek at an elevation of 28 feet above the creek swamp. As shown by the foregoing section the top of the limestone bed in the well is 25 feet beneath the surface, therefore it is 3 feet above the creek swamp level. The creek channel is almost along the strike of the rock so exposures would be expected down-stream from the well. Such is not the case, however, within a distance of several miles. Close investigation may prove up limestone bodies on which the overburden is comparatively light.

Hamilton Place, 11 Miles Northeast by East of Montezuma (map locality D-2).—A few fragments of limestone resembling that of the Jackson group were noted on the side of a hill just east of the Hamilton residence in the extreme northwest corner of Dooly County. It is said that limestone was struck 20 feet beneath the surface in the well at the house and gone through for about 50 feet.

A ridge one-fourth mile east of the house gives evidence of a limestone soil from the character of the vegetation—hickory, white oak, red bud, and other plants which follow the limestone ridges in this section. This is at the same horizon as the hillslope where the limestone was seen near the house. Neither exposures in place nor float were seen. This ridge is said to be the continuation of Mossy Ridge which begins south of Perry.

One-fourth mile northeast of the house an arenaceous, fossiliferous marl resembling bed 10 of Taylors Bluff, 3 miles above Hawkinsville, Pulaski County (see page 107), was struck 9 feet beneath the surface. It was gone through for about 20 feet and the well then abandoned. The stone is evidently of the Jackson group from its geographic position and horizon.

J. M. Carter Place (map locality D-3).—There are several exposures of highly fossiliferous fullers earth, or argillaceous limestone in which the calcium carbonate is due mainly to fossil Bryozoa, on the J. M. Carter place, 1½ miles southeast of Lilly. The limestone is very soft and friable, being easily worked with a pick. Two of the exposures are at "limestone" springs about 2000 feet from the Lilly-Vienna road, along the western edge of Pennehatchie Creek swamp. The exposures are only a few feet thick. Other exposures occur to the south along the surface of the gently sloping creek escarpment between the springs and the Lilly-Vienna road.

The stone is only a few inches beneath the surface in places on this hillslope and has been uncovered by plowing and rain washes. The hill slopes southeastward for several hundred feet on a 10 per cent grade. The limestone exposures occur up to 15 feet above the foot of the hill or the level of the swamp.

A sample of the stone taken from one of the exposures, at the western spring, shows the following analysis:

Analysis of Limestone Sample from J. M. Carter Place
(Sample No. 105)

Soda (Na_2O)	.20
Potash (K_2O)	.10
Lime (CaO)	39.82
Magnesia (MgO)	.34
Alumina (Al_2O_3) } Ferric oxide (Fe_2O_3) }	2.24
Phosphorus pentoxide (P_2O_5)	.19
Silica (SiO_2) and insoluble	23.55
Undetermined	33.56
Total	100.00
Calcium carbonate ($CaCO_3$)	71.22
Magnesium carbonate ($MgCO_3$)	.70
Total carbonates	71.92

The above analysis shows a limestone too low in calcium carbonate to be of much commercial importance. It is, however, suitable for local use for agricultural purposes.

MACON COUNTY

The limestone outcrops of Macon County occur in two formations, the Midway and the Jackson. The former covers the southern and eastern parts of the county, while the latter extends in a narrow belt along the eastern boundary.

The Midway limestone is exposed along the Flint River near Montezuma and is similar to that in Randolph County, 9 miles north of Cuthbert, although carrying a much larger percentage of sand. This limestone bed has been subjected to active weathering agents throughout the terrane of the formation, leaving erosion knobs of the stone at wide intervals. Only a few exposures occur within the entire outcrop of the formation.

The Jackson limestone of the eastern part of the county is largely covered, only a few exposures occurring.

Easterlin Property (map locality M-1).—Good exposures of limestone occur in the east bank of the Flint River above and below the upper wagon bridge, 1 mile northwest of Montezuma, on the Easterlin property. The stone is a hard, greenish-gray, arenaceous limestone containing numerous fossils, among which a large oyster, apparently *Ostrea crenulemarginata,* is the most prominent. The sand occurs as clear quartz grains, firmly cemented by the calcium carbonate.

About one-fourth mile above the bridge there is a 2-foot bed exposed that is made up almost entirely of a large oyster, probably *Ostrea crenulemarginata.* A short distance above this outcrop there are a few float boulders of comparatively pure limestone that evidently came from the horizon just above the oyster bed.

A sample taken from the section exposed at the bridge shows the following analysis:

Analysis of Limestone Sample from Easterlin Property
(Sample No. 96)

Soda (Na_2O)	.12
Potash (K_2O)	.08
Lime (CaO)	42.56
Magnesia (MgO)	.12
Alumina (Al_2O_3) Ferric oxide (Fe_2O_3)	.92
Phosphorus pentoxide (P_2O_5)	.06
Silica (SiO_2) and insoluble	20.79
Undetermined	35.35
Total	100.00
Calcium carbonate ($CaCO_3$)	76.00
Magnesium carbonate ($MgCO_3$)	.25
Total carbonates	76.25

This deposit belongs to the Midway formation. It is apparently at the same horizon and equivalent to the limestone deposits of the Greer Cave vicinity, 9 miles north of Cuthbert, Randolph County. The exact horizon of the limestone within the formation was not determined accurately, but it is probably near the middle.

The limestone is exposed in the river bluff from 100 yards below the bridge to the same distance above. It has an exposed thickness of from 5 to 15 feet with 5 to 10 feet of overburden. The probable width of this thickness of overburden back from the bluff is 100 to 300 feet.

About one-fourth mile above the bridge the limestone is again exposed in a bluff 35 feet high, the upper 6 feet of which is clayey sand. Underlying this, the hard, arenaceous limestone has a thickness of 18 feet. Talus covers the strata from the base of the limestone to the river.

The analysis of the sample taken near the bridge shows a low-grade limestone. Owing to the high percentage of quartz sand, the stone could scarcely be worked profitably for agricultural purposes because of the enormous wear to which the grinding machines would be subjected. Also the product would be low in calcium carbonate as indicated by the analysis. The stone seems to be of sufficient hardness and strength to be used successfully for concrete aggregate and railroad ballast. If the overburden is as heavy as indicated it will be a serious detriment to economical quarry operations.

W. L. McKenzie Property (map locality M-2).—On the property of W. L. McKenzie, known as the "Blue Ruin" plantation, 11 miles east-northeast of Montezuma, near the Houston County line, there are several exposures of limestone. The best of these is in a field a few hundred feet west of the overseer's residence. Here the soft, friable cream colored limestone composed almost entirely of Bryozoa, with an occasional *Pecten perplanus* and Periarchus, is exposed for a thickness of 20 feet in a well-like sink. A sample of the stone taken from the entire thickness shows the following analysis:

Analysis of Limestone from W. L. McKenzie Property
(Sample No. 30)

Soda (Na_2O)	.02
Potash (K_2O)	.10
Lime (CaO)	52.48
Magnesia (MgO)	trace
Alumina (Al_2O_3) } Ferric oxide (Fe_2O_3) }	1.20
Phosphorus pentoxide (P_2O_5)	.04
Silica (SiO_2) and insoluble	5.23
Undetermined	40.93
Total	100.00
Calcium carbonate ($CaCO_3$)	93.75

This deposit is in the lower part of the Jackson. The stone is similar in every respect, apparently, to the limestones of the same formation in Houston, Twiggs, and Bleckley counties. The strata evidently occupy their original position, dipping slightly to the southeast.

This exposure occurs on the eastern edge of a practically level area covering about 10 acres. The overburden consists of 2 feet of soil. This level area is 15 feet above the valley to the east, thus assuring a working thickness of at least 13 feet above the drainage level. Several hundred yards to the northwest the limestone is again exposed on the southeastern edge of a limesink pond. Three or 4 feet of stone is exposed here under 3 feet of black clay-soil. This exposure is a few feet above that in the sink. The workable area here consists of several acres, provided the surface of the stone is level.

On the same property, one-fourth mile to the north, there is a knoll covered with black clay-soil and fragments of soft, white, fossiliferous limestone. The knoll covers an area of about 5 acres and has a maximum elevation of 20 feet above the bottom land, with an average several feet less. The thickness of the overburden could not be determined, but it is probably not more than a foot or two. There are several other knolls of practically the same dimensions and at the same elevation, in the immediate vicinity, but no limestone is in sight.

These deposits are about 3 miles east of the nearest point on the Central of Georgia Railway. The stone is of good quality and well suited for agricultural purposes, though too soft for road metal, concrete aggregate and like uses.

SUMTER COUNTY

With the exception of a strip along the northern and eastern borders, practically the whole of Sumter County is covered with red and mottled argillaceous sands and fossiliferous flint, all apparently residual material from the Oligocene formations. This portion of the county is gently rolling. Limestone of the Jackson group is exposed in a number of sinks in the extreme southeastern corner of the county and practically continuous in the river bluffs and escarpments from 4 miles above the Seaboard Air Line Railroad tressel to the Lee County line. The land here is level and covered with a thin layer of Pleistocene sands.

STACKHOUSE LAND COMPANY PROPERTY

All of the limestone exposures in the southeast corner of Sumter County are on the property of the Stackhouse Land Company. The most important of these will be described in the locality descriptions which follow.

Map Locality Su-1.—There is practically a continuous exposure of limestone in the Flint River banks and escarpments from the Seaboard Air Line Railway tressel to a bluff 4 miles above. The face of the stone in this bluff is partly covered in such a manner that a complete section of the layers could not be seen. There are, however, alternating layers 1 to 3 feet thick of soft, white, granular limestone and hard, white, partly crystalline limestone. The stone is similar to that near the mouth of Cedar Creek, Crisp County. The base of the limestone was 12 feet above the surface of the water of the river at the time it was inspected. The river was said to be at about mean low water mark. The limestone continues upward from this level for a stratigraphic thickness of 23 feet, while the remaining 10 feet exposed is soil and humus.

A sample of the limestone representative of the entire bed shows the following analysis:

Analysis of Limestone Sample from Bluff on Flint River, 4 Miles above S. A. L. Rwy. Tressel (Sample No. 55)

Soda (Na_2O)	.09
Potash (K_2O)	.08
Lime (CaO)	51.82
Magnesia (MgO)	trace
Alumina (Al_2O_3) / Ferric oxide (Fe_2O_3)	1.62
Phosphorus pentoxide (P_2O_5)	.16
Silica (SiO_2) and insoluble	5.05
Undetermined	41.18
Total	100.00
Calcium carbonate ($CaCO_3$)	92.50

This analysis shows the limestone to be of good grade and well suited for agricultural purposes. It will also make a medium-grade lime.

This limestone belongs to the Jackson group according to stratigraphic evidence. The beds apparently occupy their original position dipping slightly to the southeast.

This bluff or escarpment is several hundred feet in length with practically the same section given above. The apparent overburden is 10 feet, but it is quite possible that the limestone extends higher into the hill than is indicated by the exposure. This can be readily determined by sinking a few prospect holes. A quarry in this deposit could be worked to within 15 feet of the river and would not be flooded probably more than once a year. However, this deposit is somewhat more than 3 miles from the Seaboard Air Line Railway, which would be a great handicap in the profitable exploitation of the stone.

Continuing down the river the next notable outcrop is at the mouth of Spring Creek, 3 miles by river above the railroad. There is here a 14-foot exposure of alternating layers, 1 to 3 feet thick, of hard, white, partly crystalline limestone and soft, white, granular limestone containing fossils. This exposure is probably a continuation of some of the strata exposed in the bluff 1 mile up-stream. Six feet of soil and humus overlies the limestone. A sample taken from the entire face of the exposure gives the following analysis:

Analysis of Limestone Sample from Mouth of Spring Creek
(Sample No. 56)

Soda (Na_2O)	.02
Potash (K_2O)	.04
Lime (CaO)	48.04
Magnesia (MgO)	.36
Alumina (Al_2O_3) / Ferric oxide (Fe_2O_3)	2.56
Phosphorus pentoxide (P_2O_5)	.04
Silica (SiO_2) and insoluble	11.33
Undetermined	37.61
Total	100.00
Calcium carbonate ($CaCO_3$)	85.80
Magnesium carbonate ($MgCO_3$)	.75
Total carbonates	86.55

From the mouth of Spring Creek to the tressel limestone is exposed almost continuously in the river bank for thicknesses of 1 to 12 feet. The hard and soft layers are persistent throughout the length of the exposure. The overburden is always several feet.

Map Locality Su-2.—From 1 to 2 miles south and southeast of Flintside on the Stackhouse place several well-like limesinks and dug wells show excellent exposures of limestone. A sink 1 mile south of Flintside exposes 10 feet of medium hard, cream colored limestone containing fossils at the base and 15 feet of soft, white, fossiliferous limestone above. Ten feet of unconsolidated sand overlies the limestone. A field slopes, gently, southward for one-fourth mile from the mouth of the sink. A somewhat larger sink one-half mile east of the above exposes 15 feet of the soft limestone beneath which is 20 feet of harder stone. Five feet of sand overlies the limestone. There is a level area of several acres surrounding the sink.

Sample No. 34, taken from the upper soft bed in the first mentioned sink and sample No. 35 taken from the lower hard bed of the last described sink show the following analyses:

Analyses of Limestone Samples from Stackhouse Place, 1 to 1 1/2 Miles South of Flintside

Sample No.	34	35
Soda (Na_2O)	.10	.17
Potash (K_2O)	.12	.25
Lime (CaO)	47.86	47.36
Magnesia (MgO)	.08	.04
Alumina (Al_2O_3) / Ferric oxide (Fe_2O_3)	.80	1.92
Phosphorus pentoxide (P_2O_5)	trace	.04
Silica (SiO_2) and insoluble	9.64	10.95
Undetermined	41.40	39.27
Total	100.00	100.00
Calcium carbonate ($CaCO_3$)	85.50	84.50

These analyses show rather low-grade limestones, which are, however, well suited for agricultural purposes.

The stone of these deposits seems to be equivalent to the exposures in Crisp County along the river and in the sinks near the river. A peculiarity is that the limestone of the river bank exposures has thin layers of partly crystalline stone at apparently the same horizon of the outcrops in the sinks where the crystalline stone does not occur. The deposits belong to the Jackson group. The strata are practically level or dip slightly to the southeast.

Both of the deposits exposed in the two sinks mentioned could be worked by pit-quarry methods to practically the level of the water in the bottom of the sinks and natural drainage still retained through underground channels. The overburden on the first mentioned deposit is 10 feet, which is rather heavy to allow economic exploitation; on the other, however, there seems to be only about 5 feet of unconsolidated sands. Both of these sinks are at least a mile from the railroad, which, considering the rather impure character of the stone, is a serious detriment to working the stone on a profitable commercial basis, at the present at least. The deposits seem to be of most value for local agricultural uses.

A well 2 miles southeast of Flintside in a broad level field exposes a soft bed of limestone 10 feet beneath the surface. One mile southeast of this well the stone is again exposed in the second terrace escarpment. Eight feet of sands overlie 5 feet of soft white limestone with several feet of harder white limestone beneath containing Foraminifera and a large Echinoid. A considerable quantity of stone could be worked along the gentle slope of the escarpment with the removal of very little overburden.

SCHLEY COUNTY

The major portion of Schley County is within the terranes of Upper Cretaceous strata and the Midway formation. As far as known there are no notable exposures of limestone in the county and but one exposure of marl, which is described in the description to follow.

Burke Place (map locality Sc-1).—An exposure of blue, sandy marl is exposed in the bed of a small stream on the W. Z. Burke place, 3½ miles northeast of Ellaville. The thickness of the marl bed could not be determined, but there is about 1 foot exposed. It underlies 4 or 5 feet of soil and humus in the narrow stream valley. A sample of the marl shows the following chemical composition:

Analysis of Marl from Burke Place, 3 1/2 Miles Northeast of Ellaville (Sample No. 95)

Soda (Na_2O)	.18
Potash (K_2O)	.16
Lime (CaO)	38.78
Magnesia (MgO)	.13
Alumina (Al_2O_3) } Ferric oxide (Fe_2O_3) }	1.22
Phosphorus pentoxide (P_2O_5)	.08
Silica (SiO_2)	28.57
Undetermined	30.88
Total	100.00
Calcium carbonate ($CaCO_3$)	69.20
Magnesium carbonate ($MgCO_3$)	.27
Total carbonates	69.47

Walls Crossing.—A bed of hard, gray, fossiliferous limestone 1 foot thick is exposed along a small branch 150 yards northwest of Walls Crossing.

The following section is exposed:

Section Near Walls Crossing

	Feet
4. Covered to top of hill	30
3. Black, carbonaceous clay	1
2. Hard, gray, fossiliferous limestone. Ostrea sp.	1
1. Dark to light blue arenaceous clay	30(?)
	62

WEBSTER COUNTY

Webster County is within the terranes of the Jackson and Claiborne groups and the Wilcox and Midway formations, while a small area in the extreme northwestern corner of the county is covered by

Cretaceous strata. Although several of these formations contain limestone in other portions of the State, the only known exposure in this county is in the Midway. The topography of the county is rolling to hilly.

Cole Place (map locality We-1).—A hard, fossiliferous, highly arenaceous limestone is exposed at Lime Spring on the Cole property, 2 miles southeast of Preston. The exposures are not continuous, but together show a stratigraphic thickness of 14 feet in the southern escarpment of Kinchafoonee Creek. Overlying the limestone and extending to the top of the scarp is 26 feet of unexposed material.

A sample secured for analysis shows the following composition:

Analysis of Sample from Cole Place, 2 Miles Southeast of Preston (Sample No. 94)

Soda (Na_2O)	.00
Potash (K_2O)	.00
Lime (CaO)	41.77
Magnesia (MgO)	.06
Alumina (Al_2O_3) } Ferric oxide (Fe_2O_3) }	1.74
Phosphorus pentoxide (P_2O_5)	.10
Silica (SiO_2) and insoluble	23.94
Undetermined	32.39
Total	100.00
Calcium carbonate ($CaCO_3$)	74.56
Magnesium carbonate ($MgCO_3$)	.12
Total carbonates	74.68

This analysis shows a low-grade limestone. The stone may be used locally for agriculture, but the hardness and presence of about 25 per cent of sand grains would make it expensive to prepare. The stone is best adapted to use for ballast, concrete aggregate and road material.

STEWART COUNTY

The southern half of Stewart County is within the terrane of the Midway formation. The exposed materials are sands and clays and residual ferruginous argillaceous sands. The latter covers the greater portion of this part of the county.

In the northern part of the county excellent exposures of sands and argillaceous sands of the Upper Cretaceous occur in gullies frequently 100 feet deep. Strata of sandstone, frequently highly ferruginous, were seen in a number of the gullies. The Ripley formation contains a bed of fossiliferous, calcareous, fine grained sand with frequent thin strata of hard, arenaceous limestone. Exposures of these strata were seen in a number of localities, about 40 feet above the stream beds. Sandy limonite occur at the top of a number of the hills which frequently rise as high as 200 feet above the lowlands. The region is very rough and but sparsely settled.

No calcareous strata of workable thickness, containing sufficient calcium carbonate to be of value for agricultural or other purposes, were seen in the county.

RANDOLPH COUNTY

Randolph County is within the terranes of the Midway, Wilcox and Claiborne formations of Eocene age and residual material of the Oligocene formation. The Eocene covers the northwestern part of the county and has the only outcrops of limestone in that part of the county. The Wilcox and Claiborne in this section consist of sands and clays while the Oligocene material is residual ferruginous sands and clays of fossiliferous flint or chert. Within the outcrops of the Midway formation the topography is characterized by steep hills 100 to 200 feet above the valleys. The other parts of the county are more gently rolling.

All of the limestone deposits of this county are from 2½ to 4 miles from the nearest railroad, with a rather rough country between, and are therefore of little value at the present, except for local use, nevertheless they are exceptionally pure.

Greer Cave Property (map locality R-1).—Exposures of limestone occur on the hill in which Greer Cave is situated, 9 miles north of Cuthbert, on the property of J. W. Wade. Near the spring at the southern end of the hill a few feet of hard, calcareous sandstone is exposed. The exact thickness of this bed could not be determined, but it is probably not more than 5 feet. A hard, pinkish to light dove colored, partly crystalline, fossiliferous limestone overlies the sandstone and is exposed at rather wide intervals to the top of the hill, 25 feet above the lower bed. The cave, 200 yards east of the southern end of the hill, exposes 10 feet of hard, light dove colored limestone that breaks rather easily with an irregular fracture.

A sample secured from an 8-foot section of the more pure limestone near the spring shows the following analysis:

Analysis of Limestone Sample from Greer Cave Property
(Sample No. 44)

Soda (Na_2O)	.00
Potash (K_2O)	.00
Lime (CaO)	54.44
Magnesia (MgO)	.28
Alumina (Al_2O_3) / Ferric oxide (Fe_2O_3)	.38
Phosphorus pentoxide (P_2O_5)	.04
Silica (SiO_2) and insoluble	1.74
Undetermined	43.12
Total	100.00
Calcium carbonate ($CaCO_3$)	97.19
Magnesium carbonate ($MgCO_3$)	.58
Total carbonates	97.77

This analysis shows an excellent grade of limestone well suited for agricultural uses and the manufacture of building lime.

The deposit belongs to the upper part of the Midway formation. The fossils recognized were: *Ostrea crenulimarginata* Gabb, *Venericardia planicosta* Lam, *Protocardia* [*nicolleti* Conrad(?)], Pecten sp., Ostrea small sp., Turritella sp., and others that were not well preserved. The limestone appears to be an erosion knob with residual and recent sands and clays surrounding it. No data as to the dip of the strata could be secured. There is no evidence of local or regional disturbance, hence the body is probably in its original position, dipping slightly to the southeast. The limestone appears to be massive or at least having no distinct bedding planes. No joints seem to have been developed.

The immediate vicinity of Greer Cave is characterized by a rugged topography. The hills are frequently as much as 175 feet above the streams. The lower 30 to 40 feet of the escarpments is Midway limestone, rarely exposed, while Wilcox sands and clays make up the upper part.

The stone of the Greer Cave deposit is exposed in small areas scattered over the surface of the hill, which is about 1000 feet wide and one-half mile long and rises 40 feet above the drainage level of the spring at the southern end. The average thickness of the limestone above the lower calcareous sandstone bed is probably between 20 and 25 feet. The outcrops indicate that the thickness of the over burden is only a foot or two.

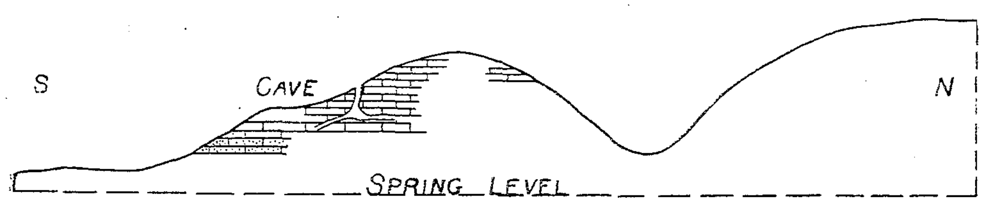


Fig. 3.—Section at Greer Cave, Randolph County

Harris Property (map locality R-2).—On the C. S. Harris place, 3 miles west of Benevolence, water-worn boulders and fragments of hard, light dove colored, partly crystalline, fossiliferous limestone cover the side of a steep escarpment on the east side of Pumpkin Creek. The stone is lithologically and paleontologically similar to that at Greer Cave (see foregoing locality description). It covers the face of the slope from the creek bottom to 35 feet above for a distance of about 300 yards. Back into the escarpment, for 300 feet, there is practically no overburden and for 400 feet farther the overburden reaches a maximum of only 10 feet.

Greer Place (map locality R-3).—Boulders of limestone are exposed in a level, oak and hickory grove 3½ miles west of Benevolence near the Cuthbert-Lumpkin public road on the property of James Greer. This limestone is similar in all respects to that described in the two foregoing descriptions. The boulders occur over an area of about 10 acres in the level woodland. A representative sample of the limestone could not be secured for analysis.

No definite idea of the extent of the limestone body could be obtained, but it seems probable that there is quite a large deposit occurring under excellent working conditions.

Seven and One-half Miles North of Cuthbert (map locality R-4).—On the Cuthbert-Lumpkin road, 7½ miles north of Cuthbert, hard, whitish, highly fossiliferous limestone is poorly exposed, being overlain by a softer fossiliferous limestone or marl. The hard stone is similar to that at Greer Cave, 1½ miles north, and apparently occurs at the same horizon. The limestone in the escarpment is largely covered by drift so that no definite idea of its extent could be obtained.

The deposit is several miles from a railroad and hence at the present the stone is of value only for local use.

CLAY COUNTY

Clay County is within the terranes of several formations—the Ripley (Upper Cretaceous), Midway, Wilcox, and Claiborne (Eocene), and residual sands of Eocene and Oligocene age. The Midway, Claiborne and later Eocene formations all contain limestone, but in this county the outcrop of the limestone is confined to the Midway.

The topography of the county is characterized in places by steep hills and escarpments rising 200 to 225 feet above the Chattahoochee River.

Jno. Harris Place, 5 Miles South of Hatcher Station (map locality Cl-1).—Limestone outcrops on the property of Jno. Harris on a low ridge, 5 miles south of Hatcher Station and one-half mile northwest of the Redding gin.

The stone is a hard, pinkish, fossiliferous variety, resembling very closely that at Greer Cave. It breaks very easily with an irregular fracture. A sample of the stone shows the following analysis:

Analysis of Sample from Harris Property (Sample No. 66)

Soda (Na_2O)	trace
Potash (K_2O)	trace
Lime (CaO)	53.92
Magnesia (MgO)	.34
Alumina (Al_2O_3), Ferric oxide (Fe_2O_3)	.56
Phosphorus pentoxide (P_2O_5)	.09
Silica (SiO_2) and insoluble	2.06
Undetermined	43.03
Total	100.00
Calcium carbonate ($CaCO_3$)	96.29
Magnesium carbonate ($MgCO_3$)	.71
Total carbonates	97.00

This deposit belongs to the upper part of the Midway formation. No data could be secured as to the dip of the beds, but they are apparently nearly level or probably dipping slightly to the southeast. The exposure is largely covered by drift, so that the bedding could not be seen.

These exposures occur around the end of a low limestone ridge some 300 or 400 feet wide and 25 feet above a spring at the foot of the bridge. The ridge has a length of somewhat less than a thousand feet at a height of about 30 feet, or 5 feet above the upper limit of the limestone exposed. There is a small pit on one side of the hill from which a few tons of the stone were removed years ago and burned for building purposes. There are other similar hills in the neighborhood on which no limestone is exposed.

The analysis shows a good grade of limestone admirably suited for agricultural uses. It would also make a fair grade of building lime and a good stone in highway construction. The distance from transportation by rail, 5 miles, eliminates the deposit at present from being of commercial importance, except for local use.

Browns Mill, Cemochechobee Creek (map locality Cl-2).—A good exposure of limestone occurs below the dam at Browns Mill on Cemochechobee Creek, 1½ miles north of Ft. Gaines. The following section was observed:

Section at Browns Mill, Cemochechobee Creek

		Feet
	3. Yellow and red sand with water-worn pebbles......	6
	(Unconformity)	
Wilcox.		
	2. Hard, white, fossiliferous limestone and friable shell marl	5
	(Unconformity)	
Midway.		
	1. Soft, white, massive bedded limestone.............	20±
		31

There is a well-defined unconformity between beds 1 and 2. Bed 1 has a very irregular surface with frequent "pot holes" 10 to 15 feet deep filled with clay.

Samples taken from this limestone show the following analyses:

Analyses of Limestone Samples from Browns Mill

Sample No.	63	64
Bed No.	2	1
Soda (Na_2O)	trace	.04
Potash (K_2O)	trace	.06
Lime (CaO)	53.86	52.26
Magnesia (MgO)	.44	1.00
Alumina (Al_2O_3) / Ferric oxide (Fe_2O_3)	2.20	2.18
Phosphorus pentoxide (P_2O_5)	.03	.06
Silica (SiO_2) and insoluble	1.09	3.68
Undetermined	42.38	40.72
Total	100.00	100.00
Calcium carbonate ($CaCO_3$)	96.16	93.36
Magnesium carbonate ($MgCO_3$)	.94	1.10
Total carbonates	97.10	94.46

There is an area covering several acres immediately surrounding this exposure with an apparent overburden of 6 or 8 feet. The surface of the limestone is so irregular, however, that prospecting is necessary before even an approximate estimate of the quantity can be made.

From the mill to the river, 2 miles, the creek has cut a narrow gorge through the limestone with perpendicular sides from 30 to 40 feet deep. The overburden is probably too heavy to allow economic working, however, prospecting may prove otherwise.

Fort Gaines (map locality Cl-3).—One of the classic exposures of Midway and Wilcox strata is about 300 yards down-stream from the wagon bridge over the Chattahoochee River at Fort Gaines. This locality has been described by Loughridge,[1] Langdon,[2] Spencer,[3] Veatch,[4] Veatch and Stephenson.[5]

Soft, white, porous limestone with a few fossils is exposed from 10 to 20 feet above low water. The unconformity between this limestone of the Midway and the overlying Wilcox sands and sandy marls is well defined. The overburden is very heavy along the river which eliminates the deposit from being of commercial importance.

CALHOUN COUNTY

Calhoun County is almost entirely underlain by the Jackson group. The soil is mainly residual sands and clay with fossiliferous flint generally distributed throughout the county. Only one or two exposures of limestone are known.

The topography is gently rolling to level along the streams with wide swamps along the larger creeks.

Spring Creek, near Arlington (map locality Ca-1).—The only known exposure of limestone in Calhoun County that is of probable economic importance is on Spring Creek, the western boundary of the county, 1½ miles above the Central of Georgia Railway tressel, 4 miles west-northwest of Arlington. The stone is a hard, white, partly crystalline variety, with a few poorly preserved fossils, breaking easily with an irregular fracture. A sample collected shows the following analysis:

Analysis of Limestone Sample from near Arlington (Sample No. 45)

Soda (Na_2O)	trace
Potash (K_2O)	trace
Lime (CaO)	55.16

[1] Loughridge, R. H., Tenth Census, Vol. VI, Cotton Production of Ga., p. 14.
[2] Langdon, D. W., Report on the Geology of the Coastal Plain of Alabama: Ala. Geol. Survey, 1894, p. 406.
[3] Spencer, J. W., First Report of Progress: Ga. Geol. Survey, 1890-91, p. 46.
[4] Veatch, Otto, Clay Deposits of Georgia: Bull. Ga. Geol. Survey, No. 18, 1909, p. 80.
[5] Veatch, Otto, and Stephenson, L. W., Geology of the Coastal Plain of Georgia: Bull. Ga. Geol. Survey, No. 26, 1911, p. 231.

Magnesia (MgO)	.04
Alumina (Al_2O_3) / Ferric oxide (Fe_2O_3)	.34
Phosphorus pentoxide (P_2O_5)	.00
Silica (SiO_2) and insoluble	1.40
Undetermined	43.06
Total	100.00
Calcium carbonate ($CaCO_3$)	98.60

This is an exceptionally pure stone, well suited for practically all purposes to which limestone is applied. The stone is also of sufficient hardness to make a rather low-grade ballast material, concrete aggregate and foundation for highways.

This stone bears a very close resemblance to the limestone at Armena, Palmyra, and Leesburg, and is probably the same horizon in the Jackson group. A few fossils were seen, but they were very poorly preserved. It is apparently thin-bedded without distinct planes between. No data as to the dip of the beds could be collected, but they probably dip slightly to the southeast.

This exposure extends for about 200 yards along the escarpment on the east side of Spring Creek, with a stratigraphic thickness of 15 feet above the creek swamp. Overlying the limestone is 6 feet of residual ferruginous sands with limonite-sand concretions the size of buckshot. Eastward from the edge of the escarpment is a level field covering about 10 acres, which is on a level with the top of the escarpment. There are other much larger areas at about the same level surrounding this field.

Information was received from T. Poole Maynard of the firm of Maynard and Simmons, Atlanta, who drilled the deposit, that the limestone extends at least 60 feet below the top of the exposure.

Cordray Mill (map locality Ca-2).—Veatch[1] gives the following description of an exposure in the northern part of the county: " * * *

[1] Veatch, Otto, Geology of the Coastal Plain of Georgia: Bull. Ga. Geol. Survey, No. 26, 1911.

* * * Probably Jackson occurs in the left bank of Ichawaynochaway Creek at Bateman 'Hammock,' 1½ miles below Cordray Mill, 12 miles east of Edison."

Section at Bateman "Hammock"

	Feet
Jackson group.	
3. Red sand	10
2. Hard, white, sandy limestone; contains a Pecten, probably *P. perplanus*, Bryozoa, and a large oyster	3
McBean formation.	
1. Aluminous sand and sandstone, slightly calcareous; *Ostrea divaricata*	1
	14

DOUGHERTY COUNTY

The whole of Dougherty County is within the terrane of limestone-bearing formations. The Chattahoochee formation occupies a narrow strip along the eastern border of the county, while deposits of late Eocene and early Oligocene age cover the remainder. The limestone exposures are confined to the banks of Flint River and the escarpments of its tributaries near the main stream. Two types of stone occur—a hard, white, partly crystalline and a soft, white to cream colored, granular limestone. Both are fossiliferous, the latter frequently being made up largely of Bryozoa.

The topography of the county is gently rolling, with the uplands from 50 to 75 feet above the river. A greater elevation is probably reached in the western part of the county.

Red, residual sands of probable Oligocene age top the plateau, with flint occurring here and there. The first terrace along the streams is capped with Pleistocene sands. Bored wells over the county have encountered limestone at depths varying from 50 to 150 feet.

In most of the exposures along the river limestone is visible for a thickness of less than 5 feet with a heavy overburden.

Flint River, 12 Miles above Albany (map locality D-1).—Soft, white limestone, 8 feet thick, containing Foraminifera, Bryozoa, Echinoids, Pecten, and hard calcium carbonate concretions, is exposed at the mouth of a small stream, 12 miles above Albany on the east bank of Flint River. An overburden of red sands overlies the stone for a thickness of from 5 to 50 feet. The deposit is of no importance commercially, but is rather interesting from a stratigraphic standpoint.

Power Plant, near Albany (map locality D-2).—Below the dam at the power plant, 2 miles north of Albany on Muckafoonee Creek, good exposures of limestone occur in the creek bank and over a large area from which the overlying Pleistocene sands have been washed. Here, also, is seen a quantity of the stone which was excavated from the dam site. The following section is descriptive of the stone:

Section on Muckafoonee Creek, 2 Miles North of Albany

	Feet
Pleistocene.	
4. Yellow Pleistocene sands with huge flat boulders of porous flint and jasper (Oligocene) at the base. Fossils in flint: Turritella, Pitaria, Glycemeris sp., *Pecten poulsoni* (?)	10
Jackson group (Ocala formation).	
3. Soft, cream colored, friable limestone made up almost entirely of fossils. Discontinuous concretionary strata and lenses of hard, cream colored, partly crystalline limestone. Fossils: *Amusium ocalanum,* several Echinoids and numerous others. Collections made by Cooke and the writer......	5
2. Flat concretions of hard, white, partly crystalline limestone and cream colored flint, also flint replacements	2
1. Soft, cream colored, friable limestone with discontinuous layers or pockets of hard, partly crystalline limestone. Bryozoa, *Amusium ocalanum,* Echinoid spines and other fossils..............	8
	25

The following analyses show the chemical character of the stone:

Analyses of Samples from Power Plant, 2 Miles North of Albany

Sample No.	37	38
Bed No.	3	1
Soda (Na_2O)	trace	.05
Potash (K_2O)	trace	.06
Lime (CaO)	53.54	53.26
Magnesia (MgO)	.04	.08
Alumina (Al_2O_3), Ferric oxide (Fe_2O_3)	1.16	1.40
Phosphorus pentoxide (P_2O_5)	trace	.05
Silica (SiO_2) and insoluble	3.67	2.93
Undetermined	41.59	42.17
Total	100.00	100.00
Calcium carbonate ($CaCO_3$)	95.64	95.06

Stratigraphic and lithologic evidence indicate that this deposit of limestone is equivalent to those exposures along Flint River in Crisp County which have been classed with the Jackson group of Eocene (Tertiary) age. The beds evidently occupy their original position, dipping slightly to the southeast.

A field covering an area of upwards of 200 acres lies north of the deposit between the Georgia, Southwestern & Gulf Railroad and Flint River. The apparent overburden of the limestone is 10 to 12 feet. The surface of the field is about 30 feet above the river at usual low water stage.

One Mile North of Albany.—On the Georgia, Southwestern & Gulf Railroad, 1 mile north of the station at Albany, excavations have been made in the superficial sands down to the underlying limestone. The pits are about 10 feet deep. A large area has been uncovered in this way, the material having been removed for railroad construction. The level field on either side of the railroad at this point is practically continuous to a mile above the creek, 1 mile north. Prospecting is necessary to determine the extent and workability of the deposit. The value of real estate close to Albany is probably more than the underlying limestone.

One and Three-fourths Miles below Albany, Flint River (map locality D-3).—An interesting exposure of limestone occurs 1¾ miles below Albany on the east bank of Flint River. The following section describes the material visible:

Section on Flint River, 1 3/4 Miles below Albany

	Feet
3. Reddish sands	12-15
Ocala formation.	
2. Hard, deep cream colored glauconitic limestone. Contains Turritella, Bryozoa, *Plicatula densata* (?) Cardium and Venericardia near the base and *Amusium ocalanum* and Echinoid spines higher up	7
1. Soft, light gray, argillaceous limestone; fossils rare	2
	21-24

At the top of bed No. 2 there appears to be an entanglement of rope-like limonite concretions. On breaking them, however, the inner material proves to be the original limestone.

This exposure is apparently at a slightly lower horizon than the strata at the power house 2 miles north of Albany, which is correlated by Cooke with the Ocala formation of the Jackson group.

LEE COUNTY

Although the whole of Lee County is underlain by limestone formations, comparatively few outcrops occur, these being confined almost entirely to the escarpments or banks of the principal streams. The most notable exposures occur along the Flint River and Kinchafoonee and Fowltown creeks. The deposits are made up of alternating layers of hard, partly crystalline or soft, white, granular, fossiliferous limestones. All the limestone exposures are of the Jackson group.

The surface of the county is gently rolling to level, few hills being more than 50 feet above the stream beds. The upland consists of red ferruginous sands and mottled arenaceous clays, probably residual from the Oligocene, while Pleistocene sands and gravel occur on the first and second terraces along the streams.

FLINT RIVER

The banks of Flint River, the eastern boundary of the county, contain outcrops of limestone at various intervals from the northern to the southern borders of the county. The most of these exposures are from 1 to 10 feet in thickness and are overlain by heavy deposits of Pleistocene sands and gravel. There are, however, several deposits worthy of note that are described in succeeding paragraphs.

At the time these exposures were visited the stage of the river was 2 or 3 feet above the usual low water mark, according to information received from parties familiar with the stream. The elevations given in this report are with reference to the water level at the time of the visit.

With one exception the principal deposits are 6 miles or more from the nearest railroad and since the Flint River is not navigable above Albany, the limestone is at the present time of value for local use only.

Close investigation of the creek escarpments near the river, together with a few prospect pits or bore holes, would probably prove up workable deposits that were not seen during the field work for this report.

Hayslett Property, Cork Ferry (map locality L-1).—Exposures of soft, white, granular limestone occur along the old road leading westward from Cork Ferry landing to the top of the river escarpment, on the Hayslett place. The following section was seen:

Section at Cork Ferry, Lee County

	Feet
3. Red sands and gravel (Pleistocene), second terrace	6
Jackson group.	
2. Soft, white, granular limestone similar to the soft	

stone seen at other localities in the county. Fossils rare	17
1. River deposit and talus	15
River	0
	38

A short distance down-stream from the above point, hard and soft layers of limestone are exposed for several feet above the water's edge. It is probable that this is the series covered in bed 1 of the section.

A sample taken from bed 2 shows the following analysis:

Analysis of Sample from Cork Ferry, Lee County
(Sample No. 60)

Soda (Na_2O)	.10
Potash (K_2O)	.16
Lime (CaO)	50.00
Magnesia (MgO)	trace
Alumina (Al_2O_3) Ferric oxide (Fe_2O_3)	1.90
Phosphorus pentoxide (P_2O_5)	.09
Silica (SiO_2) and insoluble	7.48
Undetermined	40.27
Total	100.00
Calcium carbonate ($CaCO_3$)	89.20

As seen from the above section the limestone in sight has a thickness of 17 feet. The exposures up- and down-stream, however, indicate that the deposit extends to the water's edge and below. This gives a thickness above drainage of 32 feet, during the low stage of the river. Working to the lowest point would, however, be impracticable on account of the frequent river floods. A quarry floor at the base of the present exposure, 15 feet above the river, would be out of danger except probably once or twice a year.

The apparent overburden on the limestone is 6 feet. No definite evidence could be gathered, but it is possible that this thickness of sands and gravel is about uniform over the field, extending one-half mile westward from the top of the escarpment. Prospecting is necessary to determine the actual extent of the limestone.

The lack of means of transportation decreases the commercial value of this deposit, but it could probably be economically worked for local use.

Burke Place, 1 Mile North of Burke Ferry (map locality L-2).—At the mouth of Parsons Branch, on the Burke place, 1½ miles up-stream from Burke Ferry, 12 feet of limestone is exposed at the water's edge. The stone is the soft, white variety seen at Cork Ferry, 5 miles up-stream. A sample from the upper 5 feet shows the following analysis:

Analysis of Limestone from Mouth of Parsons Branch, Burke Place (Sample No. 39)

Soda (Na_2O)	.04
Potash (K_2O)	.04
Lime (CaO)	53.66
Magnesia (MgO)	.12
Alumina (Al_2O_3) / Ferric oxide (Fe_2O_3)	1.10
Phosphorus pentoxide (P_2O_5)	trace
Silica (SiO_2) and insoluble	2.82
Undetermined	42.22
Total	100 00
Calcium carbonate ($CaCO_3$)	95.77
Magnesium carbonate ($MgCO_3$)	.23
Total carbonates	96.00

The overburden is from 8 to 15 feet, which, together with the proximity of the river, makes it of doubtful commercial importance, either for shipment or local use.

Burke Place, 2 Miles North of Burke Ferry (map locality L-2).—Near an old turpentine still on Parsons Branch, 1¼ miles up the stream from the river, a small quantity of soft, white, granular limestone has been removed from a small spring. The spring is now filled again, so that no stone in place is visible. A sample taken from the pile shows the following analysis:

Analysis of Sample of Limestone from Old Turpentine Still, Burke Place (Sample No. 40)

Soda (Na_2O)	.10
Potash (K_2O)	.14
Lime (CaO)	48.10
Magnesia (MgO)	.14
Alumina (Al_2O_3) / Ferric oxide (Fe_2O_3)	1.44
Phosphorus pentoxide (P_2O_5)	.04
Silica (SiO_2) and insoluble	9.51
Undetermined	40.53
Total	100.00
Calcium carbonate ($CaCO_3$)	85.90
Magnesium carbonate ($MgCO_3$)	.30
Total carbonates	86.20

On the north side of the branch is a field 8 feet above the spring from which the limestone was removed. This level is continuous over a large area of cultivated fields and piney woods. Several shallow wells, however, 10 to 15 feet deep, scattered over this district, expose no limestone. The level area is about 35 feet above the river. There were not enough exposures seen to get even a fair idea of the extent of the deposit, but it seems worthy of being prospected.

Limestone Bluff, Flint River (map locality L-3).—Good exposures of limestone occur in a bluff one-half mile long, 1½ miles up-stream from the Georgia, Southwestern & Gulf Railroad. Reddish sands and gravel of Pleistocene age cap the bluff for a thickness of from 6 feet near the southern end to 18 feet near the northern end. This material is underlain by 38 feet of soft, whitish, granular limestone containing hard concretions. A few thin layers of hard, white, semi-crystalline limestone are distributed at wide intervals through the bed. Fossils are rather scarce. A sample taken from the upper 20 feet of limestone near the middle of the bluff shows the following analysis:

Analysis of Sample from Limestone Bluff, Flint River (Sample No. 61)

Soda (Na_2O)	.02
Potash (K_2O)	trace
Lime (CaO)	52.68
Magnesia (MgO)	.18
Alumina (Al_2O_3) / Ferric oxide (Fe_2O_3)	1.78
Phosphorus pentoxide (P_2O_5)	.06
Silica (SiO_2) and insoluble	3.90
Undetermined	41.38
Total	100.00
Calcium carbonate ($CaCO_3$)	94.18
Magnesium carbonate ($MgCO_3$)	.38
Total carbonates	94.56

As mentioned above this limestone exposure has a length of about one-half mile and a stratigraphic thickness of 38 feet to the water's edge. The most serious hindrance to the economic working of the deposit would be the frequent high stages of the river. It would not be necessary, however, to work the entire thickness. A quarry floor 15 to 20 feet above low water mark would be out of danger of being flooded except probably once or twice a year.

The overburden of a large area at the top of the escarpment ranges from 6 feet, along the southern edge, to 15 feet farther north, as is evident from the present exposures. Prospecting is necessary to gain accurate knowledge of the actual extent of the deposit.

KINCHAFOONEE CREEK

Kinchafoonee Creek describes a southeasterly course from the northwestern part to the center of the southern boundary of the county. From 3 miles northwest of Leesburg to 1½ miles below Palmyra the banks of the creek are usually perpendicular with short stretches of swamp at wide intervals. Two terraces are recognizable, the first about 15 feet, and the second from 30 to 35 feet, above water. The former is always covered with white Pleistocene sands, while the latter frequently is capped with the same material, but more frequently with red sands.

Alternating layers of hard, white, partly crystalline and soft, white granular limestones are exposed in the creek bluffs. The exposures are quite numerous within the limits given above. In several places they are unbroken for as much as a mile. A stratigraphic thickness of from 1 to 28 feet of limestone outcrops. The usual exposure, however, is less than 10 feet, with sands overlying to the surface of the first terrace. The most important exposures will be described in succeeding paragraphs.

This limestone belongs to the Jackson group. The beds are in their original position with a dip to the southeast of slightly more than the fall in the stream.

J. R. Smith Property (map locality L-4).—An exposure of limestone occurs on the property of J. R. Smith of Atlanta at the head of a small branch one-fourth mile east of the Leesburg-Dawson road, 5 miles from Leesburg and one-fourth mile southwest of Kinchafoonee Creek.

The lower 6 feet of the stone is hard, white, and partly crystalline with 14 feet of poorly exposed limestone overlying. The latter outcrops as ledges of medium hard, white, granular limestone. It is probable that a soft material of the same general character lies between the harder strata. All of the stone breaks easily with an irregular fracture.

A sample for analysis taken from the exposures shows the following analysis:

Analysis of Limestone Sample from J. R. Smith Property, 5 Miles Northwest of Leesburg (Sample No. 93)

Soda (Na_2O)	trace
Potash (K_2O)	trace
Lime (CaO)	53.98
Magnesia (MgO)	.14
Alumina (Al_2O_3) / Ferric oxide (Fe_2O_3)	.46
Phosphorus pentoxide (P_2O_5)	.04
Silica (SiO_2) and insoluble	2.64
Undetermined	42.74
Total	100.00
Calcium carbonate ($CaCO_3$)	96.50
Magnesium carbonate ($MgCO_3$)	.30
Total carbonates	96.80

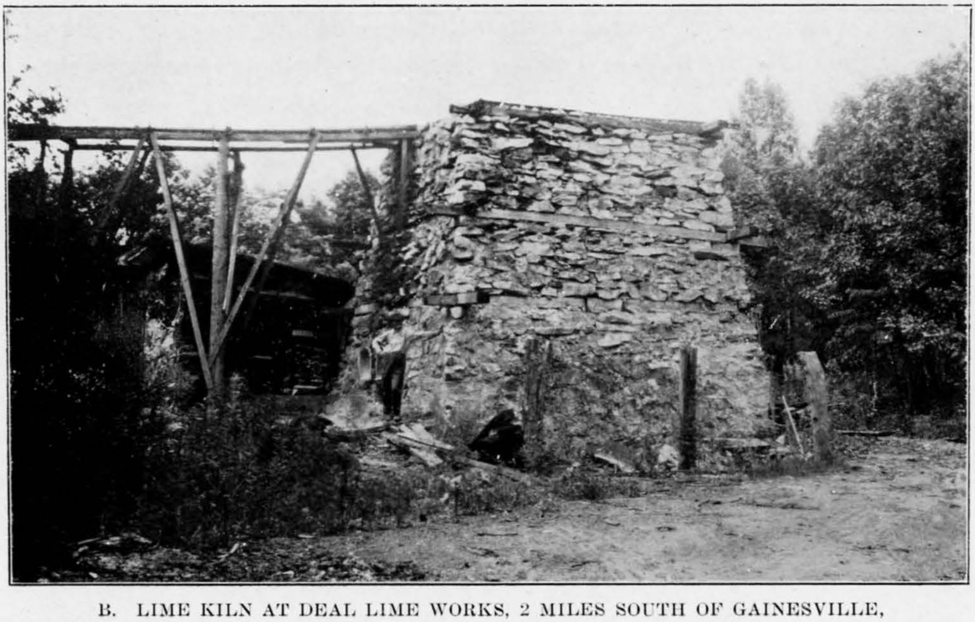
This deposit is in the form of a small knoll, covering slightly more than an acre at the base, with a maximum height of 20 feet above the spring near by. Exposures occur at frequent intervals over the surface. A quarry in this deposit would have natural drainage if the floor is kept slightly above the level of the spring. The overburden consists of about a foot of soil.

There are broad fields surrounding this deposit at a level slightly below the top of the knoll covered with red sands and mottled clays, both of which contain iron concretions the size of buckshot. This material is probably residual from the Oligocene. Prospecting is necessary to accurately determine the thickness of the limestone bed.

The quantity of limestone in sight is too small to be of much commercial importance except for local use.

One and One-half Miles below Leesburg (map locality L-5).—On

A. PRIMITIVE LIME KILN ON SMALL PROPERTY, 4½ MILES EAST OF KATHLEEN, HOUSTON COUNTY.



B. LIME KILN AT DEAL LIME WORKS, 2 MILES SOUTH OF GAINESVILLE, HALL COUNTY.

the west bank of Kinchafoonee Creek, 1½ miles below the Leesburg-Dawson public road, the following section is exposed:

Section 1 1/2 Miles below Leesburg-Dawson Road, Kinchafoonee Creek

	Feet
3. Pleistocene sand (2nd terrace)	3
2. Alternating thin beds of hard and soft, white, granular limestone	18
1. Soft, white, granular limestone; Bryozoa and a large oyster	4
	25

The perpendicular face of the bluff made it impracticable to secure a sample of the limestone for analysis.

This exposure extends along the creek for several hundred feet with a broad area extending eastward on a level with the top of the escarpment. Closer investigation or prospecting is necessary to determine the extent of the limestone body.

This section is repeated in a bluff one-eighth mile down-stream on the same side of the creek. The thickness of the limestone and the overburden is here the same, but the level area back from the top of this escarpment is larger. Together the two areas cover several hundred acres.

As seen from the above section the overburden consists of 3 feet of sand. It would probably be impracticable to work the entire thickness of stone on account of the frequent high stages of the creek. With such a light overburden, however, the floor of the quarry could be kept high enough to be out of danger of floods except during unusual seasons.

Across the creek from the lower bluff, limestone is exposed for a thickness of 12 feet with 3 feet of Pleistocene sands overlying. This deposit is too near the water to be worked economically on a large scale.

Bridge West of Century (map locality L-6).—In the escarpment on the west side and 100 yards from Kinchafoonee Creek, hard, white, partly crystalline limestone is poorly exposed 25 feet above the water. The soft stone that is inter-stratified with the hard at other exposures on the creek is not visible, being covered by drift and humus. The deposit is overlain by 7 feet of red sands, the cap of the second terrace. A broad level field covering a thousand acres or more continues westward from the escarpment. The exposures were so poor that a representative sample could not be obtained.

East Bank of Kinchafoonee Creek, 1 Mile above Palmyra (map locality L-8).—On the east bank of Kinchafoonee Creek, 1 mile above the mouth of Fowltown Creek, the following section is exposed in a perpendicular bluff for a distance of about 200 feet. (See Fig. B, Plate IX.)

Section on Kinchafoonee Creek, 1 Mile North of Palmyra

	Feet
3. Sands (second terrace)	4
2. Alternating thin strata of hard, partly crystalline and soft, white, granular limestone	21
1. Soft, whitish, granular limestone; Bryozoa	6
	31

A large area lies east from the exposure at about the level of the top of the escarpment.

As is the case with the other deposits along the creek, if the entire thickness is worked the quarry will be flooded at frequent intervals. However, a quarry floor 10 to 15 feet above the water would probably be out of danger.

Rawson Property, Palmyra, 5 Miles Northwest of Albany (map locality L-8).—An escarpment on the southwest side of the mouth of Fowltown Creek, on the Rawson place, shows rather poor exposures of 30 feet of alternating layers of hard and soft limestone. The hard stone is partly crystalline while the soft is granular. The stone is apparently very similar to that exposed along the Flint River in Crisp County and is probably the same horizon.

A sample of the stone secured as generally as possible from all the exposures shows the following chemical composition:

Analysis of Limestone Sample from Mouth of Fowltown Creek, Lee County (Sample No. 103)

Soda (Na_2O)	.14
Potash (K_2O)	.05
Lime (CaO)	54.04
Magnesia (MgO)	.12
Alumina (Al_2O_3) / Ferric oxide (Fe_2O_3)	.82
Phosphorus pentoxide (P_2O_5)	.02
Silica (SiO_2) and insoluble	2.75
Undetermined	42.06
Total	100.00
Calcium carbonate ($CaCO_3$)	96.54
Magnesium carbonate ($MgCO_3$)	.26
Total carbonates	96.80

The analysis shows an excellent grade of limestone, well suited for agricultural purposes. It will also make a fair grade of lime. As mentioned above the stone is exposed for a stratigraphic thickness of 30 feet. For another 10 feet there are frequent boulders exposed. Overlying the upper boulders there is 10 feet of red sand. In the public road cut 150 yards west of the exposure the irregular surface of the limestone is covered by from 6 to 10 feet of red sand gravel.

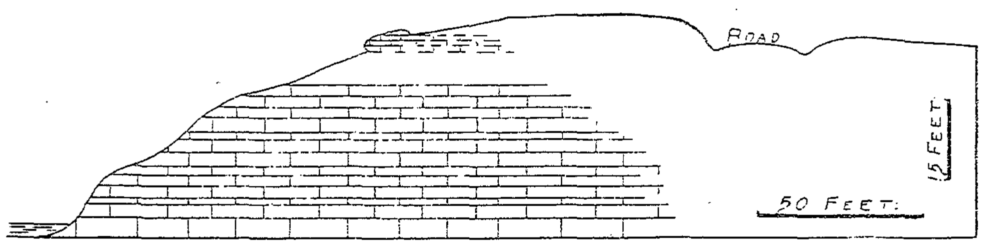


Fig. 4.—Section showing limestone on Rawson property, Lee County

The nearest point on the Albany-Dawson division of the Seaboard Air Line Railway is about 1½ miles southwest of the deposit.

The limestone exposures continue down Kinchafoonee Creek 2 miles below the mouth of Fowltown Creek. With the exception of the above mentioned bluff, which is several hundred yards long, the limestone exposures do not exceed 12 feet in thickness and underlie 3 to 10 feet of sands.

FOWLTOWN CREEK

Fowltown Creek has a southeasterly course through the southwest corner of Lee County and empties into Kinchafoonee Creek at Palmyra, 5 miles northwest of Albany. Unlike the latter stream, there is a narrow swamp along Fowltown Creek for its entire course in the county. On both sides of the swamp, however, escarpments rise from 20 to 30 feet above the bottom land. They are highest at the mouth of the creek and get lower as the head is approached. The respective crests, however, are about at the same level and probably belong to the second terrace.

Several exposures worthy of note occur between the mouth of the stream and Armena, near the western boundary of the county. The stone is similar to that outcropping along Kinchafoonee Creek, alternating layers of hard, partly crystalline and softer, white, granular limestone. The stone belongs to the Ocala formation. No data as to the dip of the beds could be secured; however, the dip is probably 8 to 10 feet per mile to the southeast.

The value of these deposits is enhanced by the proximity of transportation facilities; the Seaboard Air Line Railway paralleling the stream, 1 to 2 miles to the south, along its entire course in the county.

Two Miles North of Armena (map locality L-9).—Small exposures of hard, white, partly crystalline limestone occur in the north bank of a small tributary of Fowltown Creek, 2 miles north of Armena. The section here if well exposed would probably be similar to the section on Kinchafoonee Creek, thin layers of the hard limestone alternating with layers of soft, white, granular limestone. This latter material is covered by drift and humus.

The deposit, having a stratigraphic thickness of 4 to 6 feet, may be traced for several hundred feet. Overlying the limestone is 5 to 10 feet of red ferruginous sands with scattered limonite concretions. Prospecting is necessary to determine the value of this deposit.

Cocke Property (map locality L-10).—Several exposures of hard, white, partly crystalline and soft, white, granular limestone occur in the bluffs of Fowltown Creek and around a spring on the north side, on the J. F. Cocke property, 1 mile northeast of Armena. Only in a few instances is the limestone in place. The exposures consist mainly of loose boulders covering the creek escarpments.

At Indian Spring and Indian Den, 200 yards north of the creek, the stone is exposed in place for a thickness of 5 feet above the spring. The loose boulders then continue to within 3 feet of the surface of the field. A sample taken from the limestone in place and the loose pieces shows the following analysis:

Analysis of Sample from Indian Den, J. F. Cocke Place (Sample No. 41)

Soda (Na_2O)	trace
Potash (K_2O)	trace
Lime (CaO)	55.08
Magnesia (MgO)	.08
Alumina (Al_2O_3) / Ferric oxide (Fe_2O_3)	.72
Phosphorus pentoxide (P_2O_5)	trace
Silica (SiO_2) and insoluble	1.00
Undetermined	43.12
Total	100.00
Calcium carbonate ($CaCO_3$)	98.38
Magnesium carbonate ($MgCO_3$)	.17
Total carbonates	98.55

There is another exposure 800 feet west of Indian Den in which the limestone extends from the creek bed to within 3 or 4 feet of the surface of the field. Half way between these two exposures a well-like sink exposes limestone in place 4 feet below the surface. This sink is 20 feet above the creek. The field is continuous at about this level over an area of upwards of 40 acres, north of the exposures.

Near the mouth of the spring branch, 250 yards southeast of the spring, the limestone is again exposed to within 4 feet of the top of the escarpment. This point is 400 feet west of the north and south line of the Cocke and Bynes properties.

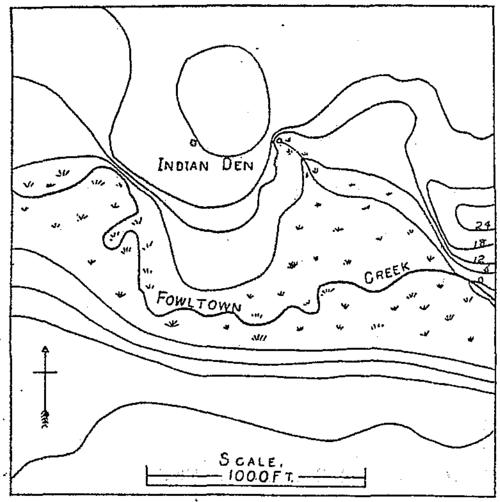


Fig. 5.—Sketch map of Cocke property, near Armena, Lee County.

The district between the creek and the Seaboard Air Line Railway at Armena is a practically level field of from 20 to 25 feet above the creek bed. No exposures occur over this area nor are there any wells to indicate the thickness of the overburden, which consists of red sands with limonite concretions, as far as can be seen.

The exposures indicate large deposits of limestone in this district under good working conditions. Prospecting is necessary, however, to give a fair idea of the actual extent and thickness of the stone.

An old kiln stands near the railroad at Armena in which at one time the limestone from near Indian Spring was burned for building purposes.

Bynes Place, 1 1/2 Miles East of Armena (map locality L-10).—The creek escarpment on the Bynes place, adjoining the Cocke place on the east, has a rather gentle slope with the field at the top extending northward from the creek for about one-half mile at a level of from 20 to 24 feet above the creek bed. One-half mile down-stream from the exposures mentioned in the foregoing locality description, boulders of hard, partly crystalline and soft, white, granular limestone cover the slope from the base to 18 feet above. This exposure, together with the one on the Cocke place near the Bynes line, indicates that this large area is underlain by limestone at a depth of 2 to 6 feet. These two exposures can hardly be relied upon for the whole area and hence prospecting is necessary to give a definite idea of the actual extent of the deposit.

North Bank Fowltown Creek, One-half Mile East of Leesburg-Newton Road (map locality L-11).—The north escarpment of Fowltown Creek becomes steep one-half mile below the Leesburg-Newton public road and contains poor exposures of the hard, partly crystalline and soft, white, granular limestone seen at other localities along the stream. The stone occurs to within 6 feet of the surface of the broad level field north of the creek and 24 feet above the swamp.

No definite idea could be obtained as to the actual extent of the deposit, but it seems probable that it underlies the entire field at approximately the depth indicated above. Prospecting is necessary to determine this, however.

Miller Place, South Bank Fowltown Creek (map locality L-11).—Inter-stratified layers of hard, white, partly crystalline and soft, white, granular limestone are exposed on the Miller place, in an old roadway, 1 mile above the mouth of Fowltown Creek on the south side. The following analysis shows the chemical character of the stone.

Analysis of Limestone from Miller Place, 1 Mile Up-stream from Mouth of Fowltown Creek (Sample No. 43)

Soda (Na_2O)	trace
Potash (K_2O)	trace
Lime (CaO)	54.26
Magnesia (MgO)	.04
Alumina (Al_2O_3) } Ferric oxide (Fe_2O_3) }	.70
Phosphorus pentoxide (P_2O_5)	trace

Silica (SiO_2) and insoluble	2.13
Undetermined	42.87
Total	100.00
Calcium carbonate ($CaCO_3$)	96.86
Magnesium carbonate ($MgCO_3$)	.08
Total carbonates	96.94

The limestone has a thickness of 15 feet overlain by 6 feet of red sands. From the top of the escarpment to the Seaboard Air Line Railway, 1½ miles south, the field is practically level. This area likewise extends eastward to Kinchafoonee Creek and westward to and beyond Armena. No wells occur over this area to give an idea of the overburden, but it is likely little more than indicated by the above exposure.

Some drift limestone occurs along the south escarpment from this exposure to Armena, but no stone is seen in place.

CRISP COUNTY

The western third of Crisp County is immediately underlain by the Jackson group, which is limestone bearing, and residual red argillaceous sands and flint of the Vicksburg formation. The most of these formations are covered, however, by sands of probable Pleistocene age. The only limestone exposures are in sinks in a strip about 1½ miles wide down the Flint River and in the river banks and creek beds near the river from Gum Creek to Swift Creek.

The Altamaha beds cover the eastern two-thirds of the county except a small area in the south central border underlain by the Alum Bluff and Chattahoochee formations, according to Veatch and Stephenson. The general topography of the county is rolling to level.

Clegg Place (map locality C-1).—A small exposure of soft, white, argillaceous limestone occurs at the "lime spring" on the Clegg place, 200 yards west of the Daphne-Drayton road, 2 miles north of Daphne. This deposit is at the foot of a hill rising 20 feet above the valley.

Numerous wells on this plantation, where the surface of the ground is about level with the top of the above hill, expose no limestone at depths ranging from 20 to 35 feet.

Byrom Property (map locality C-2).—A number of limesinks on the S. B. and W. H. Byrom property, within a radius of 1 mile of Daphne Station, offer excellent exposures of a cream colored to white, argillaceous limestone, frequently called "chimney rock." Underlying this bed is a stratum of harder limestone containing Bryozoa, Orbitoides and a Pecten, probably *P. perplanus.* This lower bed is rather poorly exposed except in the sinks near Nigger Den, an old underground stream channel, three-fourths mile southwest of the station. At this point the following section is visible:

Section at Nigger Den, Byrom Property

	Feet
3. Overburden of red clayey sand and gray soil.......	18
Jackson group.	
2. Soft, porous, cream colored to white, argillaceous limestone, "chimney rock." Fossils rare........	18
1. White, fossiliferous limestone, slightly harder than overlying bed. Fossils: Bryozoa, Orbitoides and Pecten	11
Surface of water in sink....	
	47

Samples taken from the above exposure and an outcrop three-fourths mile northeast of the station, near the site of an old saw mill, show the following analyses:

Analyses of Samples from Byrom Property

Sample No.	32	33	31
Bed No.	1	2	Near saw mill
Soda (Na_2O)	.10	.12	.15
Potash (K_2O)	.08	.15	.14
Lime (CaO)	50.76	46.72	48.30
Magnesia (MgO)	.10	.06	.06
Alumina (Al_2O_3) } Ferric oxide (Fe_2O_3) }	1.50	.76	.78
Phosphorus pentoxide (P_2O_5)	.04	trace	.02
Silica (SiO_2) and insoluble	6.62	10.93	7.84
Undetermined	40.80	41.26	42.71
Total	100.00	100.00	100.00
Calcium carbonate ($CaCO_3$)	90.76	83.30	86.30
Magnesium carbonate ($MgCO_3$)	.21	.13	.13
Total carbonates	90.97	83.43	96.43

The silica is partly in the form of minute clear quartz grains. There also occur spicules of sponges and a very small species of coral, both replaced by a mineral, apparently glauconite, insoluble or only slightly soluble in hydrochloric acid. The larger proportion of insoluble impurity seems to be in the form of clay.

These limestone strata belong to the Jackson group and probably are near the middle of the series. The contact of the two strata exposed is not of sufficient extent in any one exposure to determine accurately the dip of the bed, comparison with other outcrops, however, indicate that the beds are almost horizontal or dipping slightly to the southeast. No indications of either regional or local disturbances were seen. No joints seem to have been developed. Immediately overlying the limestone is a varying thickness of reddish, clayey sand, probably residual from limestone.

The best exposures on this property occur near Nigger Den, three-fourths mile southwest of the station and 300 yards north of Hugunen Ferry on the Flint River. Two hundred yards east of the Den there is exposed in a long narrow limesink, through which a large stream of water flows, 29 feet of limestone with 18 feet of overburden. South of the sink there is a level field covering several acres, the surface of which has an elevation of 47 feet above the underground stream, and 50 feet above the water of the Flint River, 200 yards to the south. At the time the observations were made the river was a few feet above low water.

This exposure can be traced to the Den where the stone outcrops again in practically the same section. The samples, Nos. 32 and 33, of which the analyses are given on a preceding page, were secured at this point from the entire thickness of the exposure. It is entirely probable that the upper limit of the limestone is several feet above the top of the exposure. No wells or pits were available from which this could be determined.

North of the line of outcrop from the long narrow sink to Nigger Den there is a narrow strip of bottom land 20 feet above the level of the water in the sinks or 9 feet lower than the top of the limestone exposure. The overburden covering of this area could not be determined without prospecting.

Natural drainage for quarries in the foregoing deposits may be retained by working the upper 30 feet of the limestone.

Near the site of an old saw mill, 1 mile northeast of Daphne Station, there is a limesink exposing 10 feet of soft argillaceous limestone, with a 10-foot overburden, similar to bed No. 2 of the section at Nigger Den. This sink contains water to the base of the outcrop and is at least 20 feet deep below this level. Two hundred feet south of the sink a well shows the limestone to be 10 feet below the surface. Another exposure 100 yards east of the well shows the same thickness of overburden.

In two other sinks 300 and 500 yards, respectively, south of the above sink, similar limestone is exposed from 12 feet below the surface of the surrounding field to the water in the bottom of the sink, 10 feet lower. In the southernmost of the sinks a bold stream of water flows northward, which would indicate that all of these sinks are along an underground stream. Sample No. 31, see analysis on the preceding page, was taken from the outcrop to the south over the entire thickness of the exposure.

The field immediately surrounding these sinks covers an area of about 100 acres, the surface of which has an elevation of 10 to 12 feet above the limestone. West of the line of sinks there is a large level area covering several hundred acres with an elevation of about 20 feet above the limestone. The "Big House" is in the center of the latter area.

Another exposure occurs at "Jacobs Well," a limesink one-half mile northwest of the station or one-half mile southwest of the "Big House." The stone here is similar to bed No. 1 of the section at Nigger Den, only 1 foot of stone, however, is exposed above the water in the sink. Immediately surrounding the sink is a field covering a few acres, some 6 feet above the limestone. It then gradually rises to the elevation of the field mentioned in the foregoing paragraph.

Two hundred yards west of Daphne, on the south side of the railroad, the soft, argillaceous limestone is again exposed in Blue Spring, the mouth of an underground stream flowing about 1000 gallons of clear blue water per minute. The overburden here seems to be about 20 feet.

Across the railroad from the spring there are several deep sinks exposing limestone in their bottoms under an overburden of at least 20 feet.

The following is the log of the Byrom artesian well between the station and the mill on Gum Creek, about 300 yards apart:

Log[1] of Byrom Well, Daphne, Crisp County

	Feet
Yellow clay to	54
Limestone to	82

[1] McCallie, S. W., Underground Waters of Georgia: Bull. Ga. Geol. Survey, No. 15, 1908, p. 94.

Cavity to	90
Limestone to	100
Cavity to	114
Bluish clay to	154
Dark colored sand to	250
Limestone, flint and sand to	304

This log indicates that the limestone occurs to a depth of 144 feet below the surface of the ground at this point. The drill record shows the upper 54 feet to be "yellow clay." The surrounding exposures indicate that this thickness was originally occupied by limestone, hence the clay is probably residual and of local occurrence. The cavities were probably dissolved out of the limestone. The surface of the ground at the well is 15 feet lower than the field to the south or 11 feet lower than the top of the limestone exposure at Nigger Den three-fourths mile to the southwest. Hence, the probable thickness of the limestone is 125 feet.

It seems, from the above data, that the overburden on the limestone of all the exposures on the Byrom property is rather heavy, but not necessarily prohibitive to development. The exposures were not of sufficient number to give an accurate idea of the extent of the entire deposit, hence, prospecting is necessary.

On account of the comparatively flat surface of the section it would be necessary to work the limestone by pit-quarry methods. Natural drainage could be retained by working the upper 30 feet of the deposit only.

The chemical analyses show rather low-grade limestones best suited for agricultural uses.

Averitt Place (map locality C-3).—Two exposures of limestone occur on the Averitt place, 1 mile south of Daphne Station. One exposure is in a small valley 150 yards south of the Cordele-Americus highway and 1000 yards east of Flint River. The stone here is a medium soft, highly fossiliferous, white limestone. The fossils are mainly Bryozoa with an occasional Pecten. The other exposure occurs in a sink about 300 yards east of this exposure, at which point 17 feet of earth overlies 23 feet of limestone. The stone is a soft, glauconitic, argillaceous limestone with a harder, fossiliferous ledge on top. The soft stone is similar to that occurring on the Byrom property previously described, while the harder stone is similar to that of the first mentioned exposure in this paragraph. A sample taken from the 5-foot exposure in the gulley on this property shows the following analysis:

Analysis of Limestone Sample from Averitt Place

Soda (Na_2O)	trace
Potash (K_2O)	.06
Lime (CaO)	47.62
Magnesia (MgO)	.32
Alumina (Al_2O_3) / Ferric oxide (Fe_2O_3)	1.26
Phosphorus pentoxide (P_2O_5)	.56
Silica (SiO_2) and insoluble	6.78
Undetermined	43.40
Total	100.00
Calcium carbonate ($CaCO_3$)	85.08
Magnesium carbonate ($MgCO_3$)	.67
Total carbonates	85.75

These exposures belong to the Jackson group. The strata evidently occupy their original position, dipping slightly to the southeast.

The exposure in the valley from which the sample was taken has a vertical extent of 5 feet and is a few feet above the bottom of the gulch and 12 feet below the surface of the level field immediately west. A small quantity of this stone has been excavated and burned for lime within recent years. This small quarry could be continued along the edge of the hill and a considerable quantity of stone removed, which at present lies under very light overburden. Back into the hill, however, the apparent overburden is too heavy to allow economic working. The stone could be worked for a few feet below the floor of the valley and drainage retained by ditching. It is of low grade, but could be used locally for agricultural purposes.

Armstrong Place (map locality C-4).—Several limesinks occur on the Armstrong place, 2 miles south of Coney. In one of these sinks limestone is exposed for a thickness of 25 feet with an overburden of 6 feet. The exposure is in such a position that a section could not be made nor could a fair sample of the stone be secured. Fragments lying at the foot of the exposure are of soft, argillaceous, granular limestone and fossiliferous limestone containing Bryozoa, both similar to other exposures of limestone in Crisp County which are described in this report.

One hundred feet west of the above exposure the apparent thickness of the overburden is 12 feet. From this point westward and southward there is a level area reaching a mile or more in both directions. Several wells in this area show only mottled sandy clay for depths of 25 to 30 feet.

A considerable quantity of limestone could be worked at this exposure before an excessive overburden would be encountered. The distance of the deposit from transportation, limits its usefulness to the contiguous plantations.

(Map locality C-4).—Other exposures of limestone on the Armstrong place are in the Flint River bluff, 1¾ miles west of the above mentioned outcrop. In this bluff the stone is exposed continuously to the mouth of Cedar Creek, 1½ miles above. At the upper end of the bluff the limestone outcrop is 15 feet thick, and continues for more than one-half mile down-stream. The visible limestone 1 mile above Cedar Creek is 38 feet thick and continues for a little less than one-half mile down-stream.

The following section of the higher bluff is descriptive of the different starta:

Section of Limestone Bluff on Armstrong Place

	Feet	In.
11. Pleistocene sands and gravel, surface of second terrace	7	
Jackson group.		
10. Mostly concealed, but with several small exposures of soft, white granular limestone and hard, partly crystalline, light gray limestone	8	

9. Hard, light gray, crystalline limestone	0	3
8. Alternating 6- to 10-inch layers of soft and slightly harder, white, granular limestone	1	6
7. Hard, light gray, crystalline limestone	0	3
6. Alternating 6- to 10-inch layers of soft and slightly harder white, granular limestone	7	6
5. Medium hard, white, partly crystalline limestone	4	
4. Soft, white, granular limestone	4	
3. Medium hard, white limestone containing Bryozoa	4	
2. Soft, light gray, granular limestone containing flint nodules	8	
1. Hard, white, partly crystalline limestone, irregularly weathered. Lunulites, Flabellum and Bryozoa	2	6
River	0	
	47	

The stage of the river was about 2 feet above low water at the time the exposure was investigated.

The section of the up-stream end of the bluff is practically the same as the lower 15 feet of the foregoing section.

Along the bluff the river has a due south course. The limestone strata here are dipping practically with the grade of the river, which, provided the true strike of the beds is east-northeast, would make the dip a few feet per mile to the south-southeast.

A sample taken from beds 5 to 10, inclusive, shows the following analysis:

Analysis of Sample from High Portion of Armstrong Bluff (Sample No. 58)

Soda (Na_2O)	.04
Potash (K_2O)	.04
Lime (CaO)	49.16
Magnesia (MgO)	.30
Alumina (Al_2O_3) } Ferric oxide (Fe_2O_3) }	4.76
Phosphorus pentoxide (P_2O_5)	.00
Silica (SiO_2) and insoluble	5.28
Undetermined	40.42
Total	100.00

Calcium carbonate ($CaCO_3$)	87.77
Magnesium carbonate ($MgCO_3$)	.63
Total carbonates	88.40

This is a comparatively low-grade limestone, but well suited for agricultural uses where the shipping distance is not too great.

The overburden of the lower portion of Armstrong Bluff is from 5 to 10 feet, which is probably continuous for the width of the first terrace, one-fourth mile. The overburden over the stone of the higher part of the bluff is 7 feet as indicated in the above section. The level area at this elevation runs northeast and east from the bluff for a distance of a mile or more. It is possible that prospect pits in this area would prove the overburden less in places than that indicated at the exposure. However, even if this be the case, the distance of the deposit from transportation would prohibit it from being of commercial importance at the present at least.

I. Williams Property (map locality C-4).—An excellent exposure of limestone occurs 100 yards down-stream from the mouth of Cedar Creek in a river bluff very similar to the Armstrong Bluff, previously described. The bluff together with surrounding land is owned by I. Williams, Raines, Ga.

The following section is descriptive of the material of the strata exposed:

Section of Limestone Bluff 100 Yards below the Mouth of Cedar Creek, Flint River

	Feet	In.
8. Unconsolidated sands of probable Pleistocene age; second terrace	18	
Jackson group.		
7. Hard, white, partly crystalline limestone	1	
6. Soft, white, granular limestone	3	3
5. Hard, cream colored, partly crystalline limestone	0	9
4. Soft, white, granular limestone	3	
3. Medium soft, white limestone; *amusium ocalanum* (?)	1	
2. Soft, white, granular, argillaceous limestone	8	
1. Hard, white, crystalline limestone	4	
River	0	
	39	**0**

The close similarity between this and the section of Armstrong Bluff is readily seen on comparison.

The following analyses are of samples taken from the face of this exposure:

Analyses of Samples from Bluff 100 Yards Down-stream from Mouth of Cedar Creek

Sample No.	36	59
Bed No.	2	3 to 8
Soda (Na_2O)	.14	trace
Potash (K_2O)	.18	.18
Lime (CaO)	44.60	50.36
Magnesia (MgO)	.08	1.00
Alumina (Al_2O_3), Ferric oxide (Fe_2O_3)	1.62	.94
Phosphorus pentoxide (P_2O_5)	trace	.12
Silica (SiO_2) and insoluble	14.14	8.66
Undetermined	39.24	38.74
Total	100.00	100.00
Calcium carbonate ($CaCO_3$)	79.60	89.90
Magnesium carbonate ($MgCO_3$)	.17	2.10
Total carbonates	79.77	92.00

The analysis of the sample from bed 2 shows 14.14 per cent insoluble material, which is probably clay.

The river at this point runs southwest which is very nearly along the strike of the beds, therefore no information as to the dip could be gained.

As indicated by the above section the overburden on the limestone is 18 feet which is, of course, too great to allow profitable quarry operation. Cedar Creek, just north of the bluff, has cut a channel through the lower soft beds of the limestone for a distance of one-fourth mile from the river. The creek bottom land is 10 to 15 feet above the bed of the stream with the limestone frequently within a foot or two of the surface. Sufficient quantities of stone for local agricultural use could be worked here comparatively cheap.

WORTH COUNTY

The northern part of Worth County is underlain by the Jackson, Vicksburg and Chattahoochee formations. The Jackson is represented by limestone strata exposed along Flint River. The Vicksburg is probably represented by residual red and mottled sands, but seems to be very thin through this section. The Chattahoochee limestone is exposed in several sinks north of Bridgeboro and is represented by residual red sands along the surface. The west slope of a ridge several miles back from the river contains the Chattahoochee strata.

The two following sections give an idea of the exposures of the Jackson limestone:

Section 5 Miles above G. SW. & G. Tressel, Flint River
(Map locality Wo-1)

	Feet
2. Pleistocene red sands and pebbles with flint of probable Vicksburg age at base	10
Jackson formation.	
1. Medium hard, white, compact limestone. Bryozoa, foraminifera	5
	15

Section One-half Mile above Dougherty County Line
(Map locality Wo-2)

	Feet
2. Flint and soil	
1. Medium hard, grayish limestone grading into white at top. Bryozoa, foraminifera	5

Other exposures occur along the river at thicknesses of from 1 to 4 feet. None are of economic value. In Lee County, limestone was seen as high as 30 feet above the river, then it is reasonable to believe that the same is the case in Worth County, just across the river. Prospecting along some of the creek escarpments would possibly prove up workable deposits.

Alford Property (map locality Wo-3).—There is an exposure of limestone in a sink 3 miles northwest of Bridgeboro, 100 yards south of the Albany road on the Alford property. This sink is in the top of a low hill in the open piney woods and has the shape of a funnel, 10 feet in diameter at the bottom, 100 feet at the top, and 40 feet deep. The following section is descriptive of the strata:

Section in Limesink on Alford Place

	Feet
3. Clayey sand subsoil and sand top soil	6
2. Hard, cream colored, fossiliferous limestone. Fossils poorly preserved. (Elevation 270 feet)	15
1. White, concretionary-like, oölitic, comparatively soft limestone	20
	41

A comparison of this section with those of other descriptions shows the similarity of the strata.

A sample taken from the entire thickness of limestone shows the following analysis:

Analysis of Sample from Alford Property (Sample No. 104)

Soda (Na_2O)	.08
Potash (K_2O)	.06
Limestone (CaO)	52.12
Magnesia (MgO)	.12
Alumina (Al_2O_3) } Ferric oxide (Fe_2O_3) }	.50
Phosphorus pentoxide (P_2O_5)	.31
Silica (SiO_2) and insoluble	6.17
Undetermined	40.64
Total	100.00
Calcium carbonate ($CaCO_3$)	93.12
Magnesium carbonate ($MgCO_3$)	.25
Combined carbonates	93.37

This analysis shows a good grade of limestone well suited to agricultural purposes. It will also make a rather low-grade lime when burned.

This limestone belongs to the Chattahoochee formation of Tertiary age, according to the lithologic and geographic evidence. The sink is another of those very numerous ones which characterize the terrane of the Chattahoochee formation.

As mentioned above the exposure is confined to the sides of the sink. The minimum overburden is 6 feet, but the average is probably considerably more since the surface of the limestone seems to be rather irregular. The hill, a large portion of which is level, covers an area of upwards of 100 acres, and has gently sloping sides. Another exposure occurs on top of the hill in a low flat sink 150 yards west of the above sink,.in the form of a large limestone boulder, 10 feet lower than the general level of the surrounding field and 10 feet lower than the top of the limestone at the other exposure.

A definite idea of the extent and workability of this deposit could not be gained from the present exposures, prospecting is necessary. Evidence furnished by neighboring exposures of the same formation indicates that the limestone is at least 100 feet thick. The deposit is sufficiently elevated above the bottom land so that drainage need not be considered. There are also underground channels leading out from the bottom of the sink. The underground water level is probably more than 100 feet below the top of the limestone.

The Georgia Northern Railroad is about 1 mile to the southwest of the deposit.

MITCHELL COUNTY

The western part of Mitchell County is underlain by two limestone-bearing formations—the Ocala (Jackson group) and the Chattahoochee. The only exposures of the stone, however, seem to be in the banks and escarpments of Flint River, the western boundary of the county, and in Cedar Sink, 5 miles northwest of Sale City. The river outcrops are of no commercial value on account of their nearness to the water and the heavy overburdens. Sections of the most prominent exposures are given in succeeding paragraphs.

There are two general types of stone occurring in the Ocala, a hard, white to cream colored and a soft, granular limestone. Both are fossiliferous, but frequently only sparsely so. The limestone is similar to that occurring in the southern part of Dougherty and the northern part of Decatur counties, and also across the river in Baker County.

(Map locality Mi-1).—A large stream of clear water issues from a vertical cavern in the limestone, 1 mile below the Dougherty County line. Here 2 feet of soft, white limestone containing Bryozoa is exposed 2 feet above the surface of the river water.

(Map locality Mi-2).

Section of Bluff 3 Miles below Dougherty County Line, Flint River, East Bank

	Feet
3. Pleistocene sands, clay and gravel	18
2. Residual, mottled, arenaceous clays with flint near base	15
1. Soft, whitish, pitted limestone	2
	35

This exposure is on the outside of a sharp bend. During stages of high water the river rapidly undermines the perpendicular bluff and works farther back into the level field on top. A bluff quite similar to the above occurs 4 miles farther down-stream.

(Map locality Mi-3).

Section of Bluff 5 Miles below Dougherty County Line, Flint River, East Bank

	Feet
3. Reddish, argillaceous sands and gravel	20
2. Gray, arenaceous clay	9
1. Soft, white, fossiliferous limestone	1
	30

(Map locality Mi-4).

Section 13 Miles above Newton

	Feet
2. Reddish sands and clay with fragments and boulders of flint	26
1. Hard, cream colored limestone; fossils rare	6
	32

Several large springs issue from the limestone.

(Map locality Mi-5).

Section 4 Miles above Newton

	Feet
2. Pleistocene sands and gravel	10+
1. Soft, gray (speckled) limestone, similar to stone occurring for several miles above and below	8
	18+

Between this section and Norman Ferry, 18 miles below Newton, a few exposures of limestone occur, rarely more than 1 foot above the water.

(Map locality Mi-6).

Section 12 Miles below Newton

	Feet
3. Reddish, argillaceous sands	15
2. Gray, yellow and purple, arenaceous clays	28
1. Boulders of hard, yellowish, irregularly weathered limestone with a few poorly preserved fossils; Amusium	2
	45

(Map locality Mi-7).—From 4 to 5 miles above the Decatur County line there is an almost continuous limestone bluff, from 10 to 18 feet high. The stone is a hard, cream colored, slightly crystalline limestone with few fossils. An overburden of 10 to 30 feet of sands

and soil covers the rock. A sample taken from the face of the bluff shows the following chemical composition:

Analysis of Sample from near Decatur County Line
(Sample No. 62)

Soda (Na_2O)	trace
Potash (K_2O)	trace
Lime (CaO)	52.84
Magnesia (MgO)	.06
Alumina (Al_2O_3) / Ferric oxide (Fe_2O_3)	2.76
Phosphorus pentoxide (P_2O_5)	.07
Silica (SiO_2) and insoluble	2.42
Undetermined	41.85
Total	100.00
Calcium carbonate ($CaCO_3$)	94.40
Magnesium carbonate ($MgCO_3$)	.13
Total carbonates	94.53

Another bluff similar to the above occurs from 1 to 2 miles above the Decatur County line.

V. M. Haygood Property (map locality Mi-8).—On the property of Dr. V. M. Haygood, 5 miles northwest of Sale City, there is an excellent exposure of strata of the Alum Bluff and Chattahoochee formations in Cedar Sink, one-half mile southwest of the plantation quarters. The sink resembles a funnel very closely, there being a wide mouth which gradually narrows until it reaches a diameter of about 15 feet, at a point 65 feet below the surface. From here to the bottom of the sink, about 70 feet below, the opening resembles a hand-dug well with smooth vertical sides. This prevented a detailed examination of the strata in this lower part of the limesink.

The following section is descriptive of the strata examined:

Section in Cedar Sink, 5 Miles northwest of Sale City

	Feet
Alum Bluff.	
5. Reddish, clayey sand containing chert fragments...	15
4. Greenish, argillaceous sand	30

Chattahoochee.	
3. Brecciated limestone in matrix of greenish, arenaceous clay	10
2. Medium hard, white limestone with concretionary-like structure, the concretions being about 1 inch in diameter. Elevation 265 feet(?)	10
1. Limestone	70
	135

This deposit is not of economic value at the present time, due to the great thickness of overburden on the limestone.

BAKER COUNTY

Although the whole of Baker County is underlain by limestone-bearing formations the exposures are confined to the banks of the Flint River and its tributaries. The greater portion of the county is covered by residual sands and flint, probably of late Eocene age. Along the river and the larger creeks near their mouths limestone of the Ocala formation (Jackson group) is exposed. These exposures are frequently continuous for miles with a thickness rarely exceeding 4 or 5 feet. The following sections give the character of the stone and its vertical extent and overburden.

Section at Jones Landing, 10 Miles above Newton

	Feet
3. Pleistocene sands and gravel	14
2. Hard, compact, cream colored limestones. Fossils rare	2
1. Medium hard, cream colored limestone	7
	23

Section at Twelve-Month Landing, 2 Miles above Decatur County Line

	Feet
2. Pleistocene sands	10-20
1. Medium hard, compact, slightly crystalline limestone. Amusium, Bryozoa, Echinoids	10
	20-30

The latter section was seen in a bluff which extends from Twelve-Month Landing to 1 mile above. On the Mitchell County side of the river the limestone is exposed for a thickness of 18 feet at one point. No exposures of economic importance could be found. The evidence presented along the river front is, however, sufficient to justify closer investigation of the district.

Weatherbee Place, Ichawaynochaway Creek.—On the Roe Weatherbee place there is an almost continuous exposure of soft, white, fossiliferous limestone in the north bank of Ichawaynochaway Creek from its mouth, the Flint River, to 2 miles above. The limestone in the bluffs is from 2 to 10 feet thick, underlying a minimum thickness of about 6 feet of black hammock soil. The exposures are entirely similar to those seen along Flint River above and below the mouth of the creek. The first terrace has a varying width, but is usually less than one-fourth mile. The second terrace escarpment is mainly huge boulders of highly fossiliferous flint. *Amusium ocalanum* are numerous. This flint continues along the slope for a mile or more. The extent of the siliceous beds under the second terrace could not be determined, but there are numerous outcrops of the rock in sinks for some distance back from the escarpment. This flint is entirely similar to that seen at a number of localities west of Flint River, namely, Chickasawhatchie Creek, 3 miles northwest of Leary, Spring Creek, Miller County, and the southern part of Early County.

The fossils of this flint indicate that it is the equivalent of the limestone strata above Albany on Kinchafoonee Creek, and, therefore, belongs to the Ocala formation.

EARLY COUNTY

Early County is within the terranes of the Claiborne and Jackson groups and deposits of late Eocene, all of Tertiary age. The last mentioned deposits are residual sands, clays, and fossiliferous flint. The log of the Blakely deep well[1] shows "yellowish, cherty limestone" between 30 and 40 feet below the surface. A deep well near Kara[2]

[1] McCallie, S. W., Underground Waters of Georgia: Bull. Ga. Geol. Survey, No. 15, 1908, p. 105.

[2] Op. cit., p. 107.

penetrates limestone from 32 feet below the surface to 120 feet. Good exposures of fossiliferous flint were seen along Spring Creek, but no limestone.

Strata of the Jackson group have been mapped by Otto Veatch as occurring over a small area along the Chattahoochee River around Saffold, but no limestone outcrops are mentioned by him in the Geology of the Coastal Plain of Georgia.

The Claiborne group occurs over a narrow strip along the Chattahoochee River from a few miles above Saffold to the Clay County line. No limestone is exposed, but marl occurs on Grimsleys Creek, 8 miles northwest of Blakely.

Grimsleys Mill (map locality E-1).—Below the dam of Grimsleys Mill, 8 miles northwest of Blakely, there is exposed a 4-foot bed of sandy shell marl overlain and underlain by bluish sands containing calcareous concretions.

A hard arenaceous, glauconitic, shell marl is exposed in the creek bed one-half mile down-stream from the mill, a sample of which shows the following analysis:

Analysis of Marl Sample from Grimsleys Mill, Early County (Sample No. 65)

Soda (Na_2O)	.20
Potash (K_2O)	.12
Lime (CaO)	41.26
Magnesia (MgO)	.04
Alumina (Al_2O_3) / Ferric oxide (Fe_2O_3)	1.46
Phosphorus pentoxide (P_2O_5)	.02
Silica (SiO_2) and insoluble	24.04
Undetermined	32.86
Total	100.00
Calcium carbonate ($CaCO_3$)	73.70

This analysis shows a rather high-calcium marl that is suitable for agricultural uses. It is doubtful, however, whether it can be worked commercially, since the stratum is only 4 feet thick and occurs in the creek bed with usually several feet of overburden on either side of the stream.

DECATUR COUNTY

Decatur County is within the terranes of the Ocala, Chattahoochee, and Alum Bluff formations with probable Pleistocene sands and gravel covering large areas in the eastern and western parts. The most prominent exposures of limestone occur in the banks and escarpments of Flint River and one or two localities on Spring Creek. West of Flint River the Ocala and Chattahoochee formations are largely covered by a variable thickness of Pleistocene sands.

The outcrops of Ocala limestone are all near the waters of Flint River and Spring Creek, and are of little or no economic importance.

The Chattahoochee limestone exposures occur near the base of a steep escarpment on the eastern side of Flint River. This high ridge is continuous from Bainbridge to the Florida State line, a distance of about 20 miles. It is said to continue down the Apalachicola River in Florida to within a few miles of the Gulf.

Three Miles below Baker County Line (map locality De-1).—On the west bank of Flint River, 3 miles below the Baker County line, 6 feet of hard, cream colored, granular, non-fossiliferous limestone is exposed at the base of the bluff. The stone has been irregularly weathered by the action of the river water.

This outcrop probably belongs to the Ocala formation. The deposit itself is of no economic value, but it shows the presence of limestone in the vicinity with the possibility of its continuance to a higher elevation.

Flint River, North of Bainbridge (map locality De-2).—From 5 to 7 miles above Bainbridge, on both banks of the Flint River, there are several bluffs exposing along their bases about 10 feet of soft, cream colored limestone with abundant fossils. This stone is near the contact with the overlying Chattahoochee formation and is probably of Ocala age. The deposits are of no commercial importance, but offer excellent opportunity for the study of the stratigraphy of the formation. Fossil collections were made here by Dr. C. Wythe Cooke, of the U. S. Geological Survey, and the writer.

Watsons Spring (map locality De-3).—A bed of hard, cream colored limestone, somewhat oölitic with Orbitoides and Pecten, occurs in Watsons Spring, 3 miles below Brinson on the west side of Spring Creek. The deposit has an exposed thickness of 2 feet above the creek level. The fossils are ratherly poorly preserved and insufficient to determine the age of the formation in the field, but it is probably Chattahoochee.

Twelve Miles below Bainbridge, East Bank of Flint River (map locality De-4).—What is probably the northernmost exposure of Chattahoochee limestone on Flint River occurs 12 miles below Bainbridge in the east bank. The outcrop is of hard, white, compact limestone containing imperfectly preserved corals. The bed has a thickness of 5 feet at the base of the bluff and is overlain by limonitic sands and river sand. This deposit is of no economic importance, but is interesting stratigraphically as it marks the approximate northern limit of the Chattahoochee formation on Flint River. Fossil collections were made here by Cooke, of the U. S. Geological Survey.

SANBORN MILL CREEK.

(Map locality De-5).—From the head of Sanborn Mill Creek, one-fourth mile west of the station at Faceville, to the Flint River, 2½ miles north, there are good exposures of the Alum Bluff and the Chattahoochee formations. The former outcrops as clays in a deep gully at the head of the branch while limestone of the latter formation is exposed almost continuously from the bottom of the gully to the river. The following is a rather ideal section, but gives a general idea of the strata:

Section from Head of Sanborn Mill Creek to the Flint River

	Feet
Pleistocene.	
11. White to gray sands	10

Oligocene.	
Alum Bluff formation.	
10. Yellow, arenaceous clay (partly covered)	25
9. White, yellow and blue clay (fullers earth)	15
8. Covered (probably clay)	15
Chattahoochee formation.	
7. Arenaceous limestone	2
6. Hard, non-crystalline limestone	13
5. Hard, whitish, crystalline limestone	30
4. Soft, white, arenaceous limestone and hard, white arenaceous limestone	
3. Calcareous sand (3 to 6 feet)	65
2. Hard and soft, white, arenaceous limestone (hard in pockets)	
Recent.	
1. Swamp deposit	15
	190

Sanborn Mill Creek has cut a narrow "V"-shaped valley along its entire course, except near the river where it is swampy. There are few limestone exposures, except in the bed and the immediate banks of the streams, and these rarely have a stratigraphic thickness of more than 10 feet. These outcrops indicate large deposits of limestone with light overburden, though the evidence is not conclusive. All of the limestone is, however, rather impure and probably of little value at the present. A few of the best exposures are described as follows:

One Mile Northwest of Faceville.—At the fork of the two branches near the southern edge of lot 286, 21st district, there are huge boulders of hard, cream colored, compact limestone, belonging to bed 6 of the above section. There are several acres of level land around the junction of the two streams largely covered by loose limestone. No sample for analysis was secured as the stone was not in place.

A limestone ridge in the northern part of the same lot runs between and comes to a point at the junction of two small streams. This stone is a hard, white, crystalline variety with a few fossils that have been distorted beyond recognition by the re-crystallization of the calcium carbonate.

A sample of this stone shows the following analysis:

Analysis of Sample of Limestone from Lot 286, 21st District (Sample No. 46)

Soda (Na_2O)	.22
Potash (K_2O)	.14
Lime (CaO)	44.78
Magnesia (MgO)	.71
Alumina (Al_2O_3) / Ferric oxide (Fe_2O_3)	1.36
Phosphorus pentoxide (P_2O_5)	.04
Silica (SiO_2) and insoluble	17.64
Undetermined	35.11
Total	100.00
Calcium carbonate ($CaCO_3$)	81.30
Magnesium carbonate ($MgCO_3$)	1.49
Total carbonates	82.79

This analysis shows a siliceous limestone, though under the hand lens it appears to be comparatively pure.

This stone belongs to bed 5 of the above section. The loose boulders give evidence that the deposit is in beds from 12 to 18 inches in thickness. The strata are apparently in their original position, dipping a few feet per mile to the southeast.

This deposit occurs in a small ridge extending west from the main creek escarpment to where a small stream enters Sanborn Mill Creek. The ridge has a width of about 150 feet at the upper limit of the exposure and a height of 30 feet above the stream bed. These dimensions decrease to 0 where the streams unite. The exposure is some 200 feet long. An overburden of probably not more than 1 or 2 feet covers the limestone.

The above analysis shows a stone that is too low in lime to be worked for agricultural purposes, except for local use. However, the stone is sufficiently hard to be used for road work, ballast and aggregate for concrete. It is also suitable for building purposes. The thin bedding will be an aid to quarrying.

This is probably the most valuable exposed deposit of limestone along Sanborn Mill Creek. The bed, however, is probably continuous along the edge of the escarpments of the streams in the vicinity. Prospecting is necessary to prove other workable deposits. These deposits are 80 feet lower than the Atlantic Coast Line Railway and 1 to 2 miles distant.

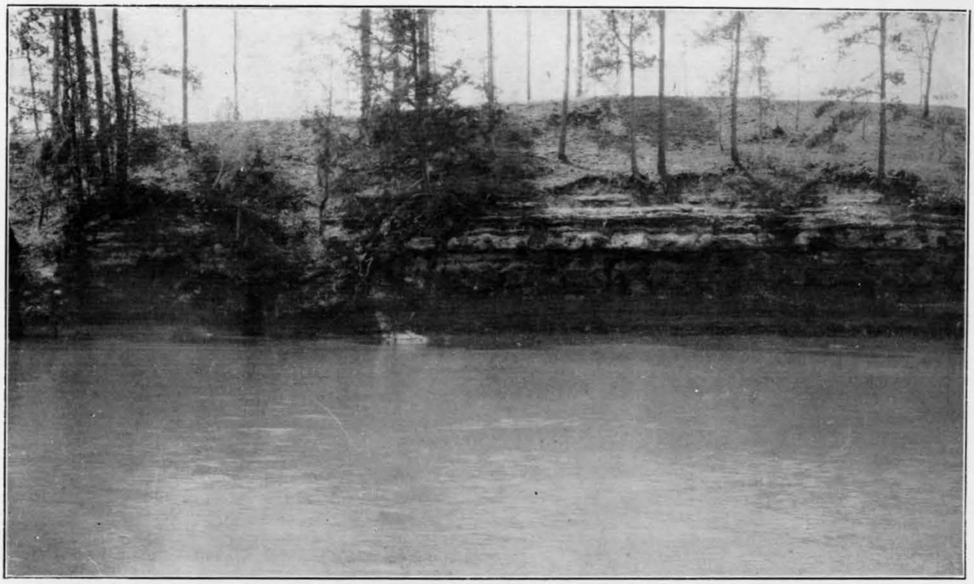
The exposures of limestone, below the above bed, along Sanborn Mill Creek and its tributaries, are quite numerous; in fact, almost continuous along the stream banks. In places the branches have cut narrow ditch-like channels through the soft, white stone. These outcrops belong to beds 2 and 4 of the above section. The analyses of samples of these stones show a magnesian limestone with high silica content in the form of small quartz grains. The stone is of little value, except locally for agricultural purposes.

A sample of the stone from the fork of the branches one-half mile from Flint River shows the following analysis:

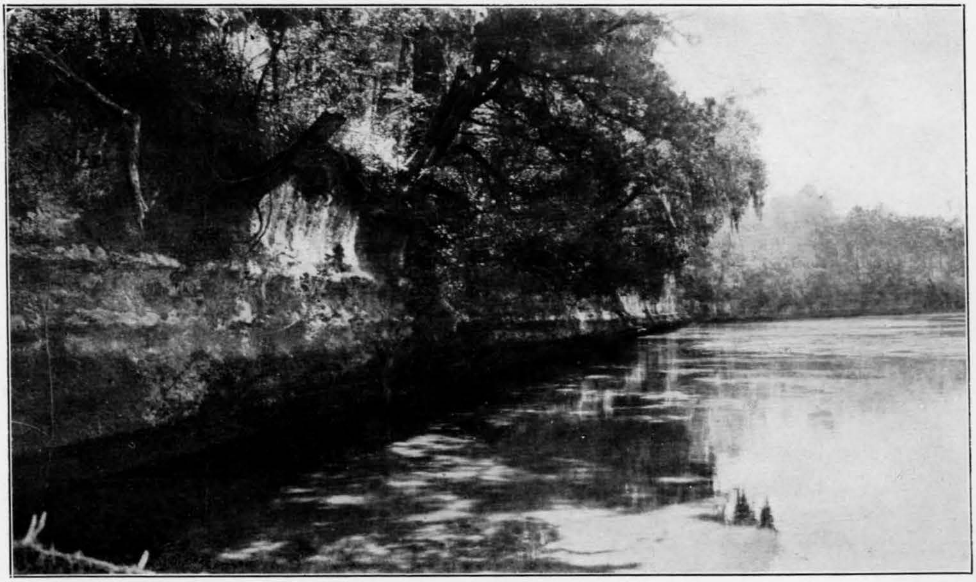
Analysis of Sample from Lot 265, 21st District (Sample No. 47)

Soda (Na_2O)	.82
Potash (K_2O)	.25
Lime (CaO)	23.86
Magnesia (MgO)	15.46
Alumina (Al_2O_3) } Ferric oxide (Fe_2O_3) }	3.16
Phosphorus pentoxide (P_2O_5)	.04
Silica (SiO_2) and insoluble	17.04
Undetermined	39.37
Total	100.00
Calcium carbonate ($CaCO_3$)	42.60
Magnesium carbonate ($MgCO_3$)	32.46
Total carbonates	75.06

This is a high-magnesian limestone containing clear quartz grains. It is one of the few samples of limestone collected in the Coastal



A. LIMESTONE EXPOSURE, WEST BANK OF OCMULGEE RIVER, 1¾ MILES BELOW HAWKINSVILLE, PULASKI COUNTY.



B. LIMESTONE BLUFF ON ARMSTRONG PROPERTY, FLINT RIVER, CRISP COUNTY.

Plain showing an appreciable percentage of magnesia, which is probably only a local condition.

The following section was noted one-fourth mile from the river on Sanborn Mill Creek:

Section One-fourth Mile from River, Sanborn Mill Creek

	Feet
4. Soil, some flint	4 to 7
3. Medium hard, white, arenaceous limestone	8
2. White, fine grained sand	3
1. Medium hard, white, arenaceous limestone	6
	24

A sample from bed 3 shows the following analysis:

Analysis of Sample from Sanborn Mill Creek, One-fourth Mile from Flint River (Sample No. 48)

Soda (Na_2O)	.39
Potash (K_2O)	.15
Lime (CaO)	43.86
Magnesia (MgO)	2.60
Alumina (Al_2O_3) Ferric oxide (Fe_2O_3)	1.30
Phosphorus pentoxide (P_2O_5)	trace
Silica (SiO_2) and insoluble	14.32
Undetermined	37.38
Total	100.00
Calcium carbonate ($CaCO_3$)	78.30
Magnesium carbonate ($MgCO_3$)	5.40
Total carbonates	83.70

The silica is in the form of clear quartz grains.

Numerous exposures of the medium hard to soft white arenaceous limestone occur along a branch that enters Sanborn Mill Creek from the northeast, in lot 265, 21st district, one-half mile from Flint River.

Analysis of Sample taken from a 10-foot Exposure, 1 1/2 Miles Up-stream from the Flint River, Lot 263,? 21st District
(Sample No. 49)

Soda (Na_2O)	.44
Potash (K_2O)	.44
Lime (CaO)	42.22
Magnesia (MgO)	.47
Alumina (Al_2O_3), Ferric oxide (Fe_2O_3)	1.48
Phosphorus pentoxide (P_2O_5)	.04
Silica (SiO_2) and insoluble	22.07
Undetermined	32.84
Total	100.00
Calcium carbonate ($CaCO_3$)	75.42
Magnesium carbonate ($MgCO_3$)	.90
Total carbonates	76.32

This analysis shows a low-calcium limestone with the silica in the form of clear quartz grains.

Another sample was taken from an 8-foot exposure one-fourth mile up-stream from the above outcrop.

Analysis of Sample from Lot 384, 20th District, Decatur County
(Sample No. 50)

Soda (Na_2O)	.32
Potash (K_2O)	.20
Lime (CaO)	41.30
Magnesia (MgO)	.90
Alumina (Al_2O_3), Ferric oxide (Fe_2O_3)	1.04
Phosphorus pentoxide (P_2O_5)	trace
Silica (SiO_2) and insoluble	23.11
Undetermined	33.13
Total	100.00
Calcium carbonate ($CaCO_3$)	73.70
Magnesium carbonate ($MgCO_3$)	1.90
Total carbonates	75.60

This is an impure limestone containing clear quartz grains as the principal impurity. It is generally soft, but contains hard calcareous concretions of irregular shapes and sizes.

W. M. Duke Place (map locality De-6).—On the W. M. Duke property, 3 miles northwest of Faceville, several low limestone ridges extend from the main escarpment toward the river. The stone is a hard, whitish, partly crystalline, fossiliferous variety, having an irregular fracture. A sample of the rocks shows the following analysis:

Analysis of Limestone Sample, W. M. Duke Place, 3 Miles Northwest of Faceville (Sample No. 51)

Soda (Na_2O)	trace
Potash (K_2O)	trace
Lime (CaO)	54.70
Magnesia (MgO)	.12
Alumina (Al_2O_3), Ferric oxide (Fe_2O_3)	.70
Phosphorus pentoxide (P_2O_5)	trace
Silica (SiO_2) and insoluble	1.38
Undetermined	43.10
Total	100.00
Calcium carbonate ($CaCO_3$)	97.70
Magnesium carbonate ($MgCO_3$)	.26
Total carbonates	97.96

This deposit probably belongs to the upper middle beds of the Chattahoochee formation. The stratum appears to be in its original position, dipping a few feet per mile to the southeast.

The best exposures occur on a ridge one-half mile north of the Duke house. Here are a number of flat outcrops of the limestone with loose fragments and boulders scattered over the surface of the ridge. Other exposures occur on similar limestone ridges east of the above. These deposits are about 100 feet above low water mark of the Flint River and are near no stream that would hinder working by flooding the quarry; consequently natural drainage can be secured.

These deposits, which are about 5 in number cover areas from 2 to 10 acres each, with an average height above the valleys of 15 to 18 feet. The overburden of soil and humus, appears to be usually less than 2 feet.

The deposits are easily accessible from both the Atlantic Coast Line Railway, 2 miles south, and the Flint River, one-half mile north, which is navigable from Albany, to the Gulf of Mexico.

The above analysis shows an exceptionally pure limestone, well suited for agricultural uses and for building lime. The stone is also hard enough to be used for ballast, aggregate for concrete and possibly road metal. The surrounding hills and bottoms are well timbered and would furnish adequate fuel for power generation or lime burning.

It is quite probable that numerous other outcrops of limestone occur along the foot of the ridge that follows down the east side of the Flint River. The region is full worthy of closer investigation than was permissible on this survey.

Recovery (map locality De-7).—From 1 to 1½ miles south of Re covery along the Atlantic Coast Line Railway, there are a number of limesinks exposing a soft, cream colored, granular, arenaceous limestone containing harder masses of a like texture from one-half to twelve inches in diameter. A sample of this stone shows the following analysis:

Analysis of Sample Secured 1 1/4 Miles Southwest of Recovery (Sample No. 52)

Soda (Na_2O)	.46
Potash (K_2O)	.12
Lime (CaO)	26.74
Magnesia (MgO)	16.47
Alumina (Al_2O_3) / Ferric oxide (Fe_2O_3)	2.16
Phosphorus pentoxide (P_2O_5)	trace
Silica (SiO_2) and insoluble	14.68
Undetermined	39.37
Total	100.00

Calcium carbonate ($CaCO_3$)	47.74
Magnesium carbonate ($MgCO_3$)	24.70
Total carbonates	72.44

This analysis shows a high-magnesian limestone containing a large percentage of silica, which is in the form of clear quartz grains. This limestone is lithologically and chemically similar to the bed from which sample No. 47 was taken.

These exposures occur in the steep sides of two or three comparatively recent limesinks, the most prominent of which is a well-like sink some 50 feet in diameter into which a small stream flows and finds an outlet through underground channels. At the time of the visit the sinks were almost full of water, so that a complete section could not be seen.

These exposures occur in a narrow flat bottom between a ridge on the north and a creek on the south, through which the Atlantic Coast Line Railway runs. The tops of the exposure are usually a few feet below the rails and are overlain, in the bottom land, by an overburden of from 0 to 10 feet.

This limestone is again exposed 1 mile farther southwest in a small stream bed beneath the railroad. Here are large flat concretions of comparatively pure limestone. The overburden is quite heavy.

This stone is probably of no value at the present time. The calcium content is too low to be worked on a commercial scale for agricultural limestone and the silica sand content prevents its being used for the manufacture of hydraulic lime.

Near Florida Line (map locality De-8).—From 300 yards north of to the Florida State line, a soft, white, siliceous limestone is exposed in the cuts along the Atlantic Coast Line Railway. No fossils could be found in the material. A sample of the limestone showed the following analysis:

Analysis of Limestone Sample from Florida Line, A. C. L. Railway (Sample No. 53)

Soda (Na_2O)	.49
Potash (K_2O)	.86

Lime (CaO)	13.40
Magnesia (MgO)	8.87
Alumina (Al_2O_3) / Ferric oxide (Fe_2O_3)	2.64
Phosphorus pentoxide (P_2O_5)	.06
Silica (SiO_2) and insoluble	47.02
Undetermined	26.66
Total	100.00
Calcium carbonate ($CaCO_3$)	23.90
Magnesium carbonate ($MgCO_3$)	18.60
Total carbonates	42.50

The above analysis shows a highly siliceous magnesian limestone or dolomite. The silica is in the form, principally, of very finely divided particles, but some fine quartz grains also occur. Better exposures of this stone occur across the State line in Florida. At one locality on the railroad, 1 mile north of River Junction, numerous fossils were seen in a flat exposure at a lower horizon than the exposures in the railroad cuts.

This stone is frequently used throughout this section for building chimneys and has hence acquired the name of "chimney rock."

GRADY COUNTY

The larger portion of Grady County is covered with sand and clays of the Altamaha formation with Alum Bluff and Chattahoochee strata exposed along the Ochlockonee River and in the southeastern and northwestern parts of the county. The surface is gently rolling to level. The limestone exposures are confined to the southern and northwestern parts of the county.

Water Falls (map locality G-1).—Probably the best exposure of the Chattahoochee and the lower part of the Alum Bluff formations occurs in the limesink known as Water Falls, 11 miles north of Whigham on the I. E. Maloy property. This sink is of comparatively recent origin, 50 feet in diameter, with perpendicular sides some 50 feet deep and then a steep slope going 50 feet deeper. The strata, especially the limestone, are similar to those seen at various localities throughout this section of the State. The following section is descriptive of the strata exposed.

Section at Water Falls

	Feet	In.
Altamaha (Lafayette(?))		
16. Drift to top of hill, reddish, sandy soil	18	
15. Yellow and gray mottled, argillaceous sand with flint fragments at base; yellow soil at top	10	
(Unconformity)		
Alum Bluff.		
14. Greenish, slightly plastic clay, exact thickness not determined, probably about	3	
13. Hard, irregular calcium carbonate concretions in a matrix of white, calcareous, sandy clay	10	
12. White, calcareous sand	6	
11. White, calcareous clay	0	6
10. White, arenaceous limestone	0	2
9. White, calcareous clay	0	6
8. White, arenaceous limestone	0	2
7. Soft, white, calcareous sandstone	6	
6. Greenish, probably calcareous sand	6	
Chattahoochee.		
5. Bed of apparently brecciated material similar to that of bed 4 in a matrix of white, argillaceous, sandy limestone	5	
4. Hard, compact, grayish limestone, fossils rare; occasional oölites; conchoidal fracture	20	
3. Hard, compact, yellowish-gray limestone with delicate, irregular brownish bands in places; fossils rare; conchoidal fracture	5	
2. Hard, white, minutely crystalline, porous limestone; concretionary-like structure; several species of cephalopods. Highly oölitic in pockets; weathers into pisolitic-like mass; pisolites one-half to 2 inches in diameter; conchoidal fracture; resembles lower bed at "Limesink"	50	
1. Medium hard, white, fossiliferous limestone. Echinoids, *Pecten (perplanus?)*, Orbitoides and Bryozoa. Bears close resemblance to limestone seen along Flint River below Newton	20	
	160	4

Samples from the different strata show the following analyses:

Analyses of Samples from Water Falls

Sample No.	71	72	73	74
Bed No.	1	2	3, 4 & 5	13
Soda (Na_2O)	trace	.06	.31	.60
Potash (K_2O)	trace	.03	.19	.23
Lime (CaO)	55.46	52.16	42.78	26.68
Magnesia (MgO)	.16	.40	1.23	5.61
Alumina (Al_2O_3) Ferric oxide (Fe_2O_3)	.32	.50	.80	1.76
Phosphorus pentoxide (P_2O_5)	trace	trace	.04	.08
Silica (SiO_2) and insoluble	.50	4.73	18.98	37.33
Undetermined	43.56	42.12	35.67	27.71
Total	100.00	100.00	100.00	100.00
Calcium carbonate ($CaCO_3$)	98.96	93.16	76.40	47.68
Magnesium carbonate ($MgCO_3$)	.34	.84	2.60	11.74
Total carbonates	99.30	94.00	79.00	59.42

As seen from the above section this limestone belongs to the Chattahoochee formation. It is massive bedded with probably a slight dip to the southeast. The water which flows into this sink during wet seasons flows out through underground channels.

This deposit has a visible vertical extent of 100 feet. One-fourth mile west of this exposure the stone of bed 3 of the above section out crops at Rock Cave. Between these two exposures there is a large field having a regular slope from the top of the former down to the latter outcrop. East of the Water Falls the overburden on the limestone consists of the complete section given above. On the west side the overburden has a maximum thickness at the mouth of the sink of 25 feet, from which point the field slopes westward. At the Rock Cave the overburden is apparently about 10 feet. Surrounding these exposures there are fields covering from 200 to 300 acres at about the same level as that immediately surrounding the cave. No accurate idea of the actual extent and workability of this deposit could be gained from the two exposures. Prospect pits are necessary.

This deposit is about 10 miles from the nearest trunk line railroad, but a log railroad which connects with the Atlantic Coast Line west of Whigham is within about 4 miles of the property.

Blowing Cave (map locality G-2).—At Blowing Cave, one-half mile north of the Water Falls, on the Barrow place, hard, white limestone similar to that of bed 2 at the Water Falls (see section) is exposed. A sample of the stone, taken principally from loose boulders, shows the following analysis:

Analysis of Sample from Blowing Cave (Sample No. 70)

Soda (Na_2O)	trace
Potash (K_2O)	trace
Lime (CaO)	54.54
Magnesia (MgO)	.30
Alumina (Al_2O_3), Ferric oxide (Fe_2O_3)	.68
Phosphorus pentoxide (P_2O_5)	.00
Silica (SiO_2) and insoluble	.95
Undetermined	43.53
Total	100.00
Calcium carbonate ($CaCO_3$)	97.34
Magnesium carbonate ($MgCO_3$)	.63
Total carbonates	97.97

This exposure is on the top of a low hill some 25 feet above the surrounding bottom land, and consists principally of loose boulders of stone with a few in the mouth of the cave probably in place. There is an overburden of apparently not more than 3 or 4 feet. The hill covers 40 to 50 acres. This deposit is at too great a distance from a railroad to be of commercial importance, but it is well situated and the stone of excellent quality to be worked for local use.

Forest Falls (map locality G-3).—At Forest Falls or Limesink, 8 miles north of Whigham, limestone is exposed in a vertical bluff 40 feet high. A small stream falls over this precipice and then finds an outlet through underground channels. The following section was observed:

Section at Forest Falls.

	Feet
9. Drift, red sand, gray sand and gravel	10 to 50
(Unconformity)	
Alum Bluff.	
8. White, calcareous, arenaceous clay with a few hard calcium carbonate concretions	8+
7. White, fine grained sand	2
6. Soft, yellowish, calcareous sandstone (7 ft.) grading into hard, white, calcareous sandstone (8 ft.)	15
Chattahoochee.	
5. Apparently brecciated hard, white, compact limestone in a matrix of soft, white, argillaceous limestone. Irregular brownish bands run through aggregate and matrix without break	3
4. Soft, white, argillaceous limestone with brownish, concentric bands	2
3. Hard, compact, yellowish, minutely crystalline limestone. Fossils rare	15
2. Hard, gray, granular limestone	3
1. Hard, white limestone with concretionary-like structure. Oölitic, small caverns with calcite crystals. Weathered in small marble-size balls. Fossils numerous, principally cephalopods	15
	73 to 113

By comparing this section with the Water Falls section the close resemblance of the strata may be observed.

Samples of this stone show the following analyses:

Analyses of Samples from Limesink

Sample No.	67	68	69
Bed No.	1, 2 & 3	4 & 5	6
Soda (Na_2O)	trace	.33	.59
Potash (K_2O)	trace	.28	.98
Lime (CaO)	50.50	23.88	12.82
Magnesia (MgO)	.46	14.60	3.31
Alumina (Al_2O_3) } Ferric oxide (Fe_2O_3) }	.76	2.80	.86
Phosphorus pentoxide (P_2O_5)	trace	.06	.04
Silica (SiO_2) and insoluble	8.63	21.88	60.90
Undetermined	39.65	36.17	20.50
Total	100.00	100.00	100.00
Calcium carbonate ($CaCO_3$)	90.26	42.68	22.92
Magnesium carbonate ($MgCO_3$)	.90	30.50	6.93
Total carbonates	91.16	73.18	29.85

This deposit is probably of little economic importance due to the useless quality of the upper beds, which are therefore overburden. On the east side, this material, together with overlying sandy soil, quickly reaches a thickness of 50 feet, while on the west side of the sink no limestone is exposed. The original sink was probably larger than the present dimensions and was subsequently partially filled by drift sands and clays from the Altamaha.

Little Limesink (map locality G-4).—Limestone is exposed in Little Limesink, 5 miles north of Whigham. The following section is descriptive of the strata:

Section at Little Limesink

	Feet
10. Covered to top of hill, gray sandy soil	7
9. Boulder of hard, gray compact limestone (in place?)	4
8. Concealed	7

7. Fine grained, yellow, cross-bedded sand, apparently in place	3
Chattahoochee.	
6. Soft, white, argillaceous, siliceous limestone; pisolitic structure; probably weathered phase of a limestone with concretionary structure	12
5. Hard, gray, compact limestone; pinkish at base. Few fossils	21
4. Hard, white, compact limestone	3
3. Greenish clay	1
2. Soft, white, siliceous limestone; probably weathered phase of harder limestone. No fossils seen	6
1. Hard, grayish, compact limestone. Pecten	15
	79

This section resembles those observed at the Limesink, 4 miles northeast, and the Water Falls, 8 miles northeast, in a general way only. These exposed strata seem to be, however, more highly weathered; it is possible that this hides the true character of the original material. Fossils here are very rare and poorly preserved. The contact of the Chattahoochee and Alum Bluff was placed in this section by comparison with other sections rather than by evidence furnished by the exposed strata.

Samples of the limestones show the following analyses:

Analyses of Samples from Little Limesink

Sample No.	75	76	77	78
Bed No.	1	2	5	6
Soda (Na_2O)	.06	.31	.36	.37
Potash (K_2O)	.04	.60	.26	.23
Lime (CaO)	46.68	40.94	35.84	19.44
Magnesia (MgO)	.80	.54	9.85	14.08
Alumina (Al_2O_3) / Ferric oxide (Fe_2O_3)	.42	.74	1.94	2.04
Phosphorus pentoxide (P_2O_5)	.06	.02	.04	.04
Silica (SiO_2) and insoluble	14.36	19.93	11.80	30.65
Undetermined	37.58	36.92	39.91	33.15
Total	100.00	100.00	100.00	100.00
Calcium carbonate ($CaCO_3$)	73.38	73.14	64.04	34.74
Magnesium carbonate ($MgCO_3$)	1.70	1.14	20.55	29.40
Total carbonates	75.08	74.28	84.59	64.14

From the evidence furnished by the analyses of the samples, all of these limestones are rather impure, probably too impure to be ground for agricultural purposes, except for local use. It is possible, however, that after being burned they would have hydraulic properties and would, therefore, make a natural cement.

The overburden, which contains a thin bed of limestone as indicated by the above section, is 21 feet. It is possible that this thin bed is much thicker than is indicated by the section.

On the whole, the existing conditions at the exposure were such that a definite idea of the extent and workability of the deposit could not be secured. The quantity of the stone and apparent overburden are such that prospecting is warranted, however, the analyses show a limestone that is suited for only the manufacture of natural cement.

There are other exposures of limestone in the northwestern part of Grady County, notably at Bay Sink, but none of them are of economic importance. At this sink Chattahoochee limestone and flint are exposed in the bottom, the sides of which are covered by soil.

James Blackshear Place (map locality G-5).—Medium hard, grayish limestone is exposed on the Jas. Blackshear place, 8 miles south of Cairo, in the escarpment on the east side of Ochlocknee River, 200 yards south of Bonnet Lake. A sample of the stone shows the following analysis:

Analysis of Limestone on the Jas. Blackshear Place, Grady County (Sample No. 90)

Soda (Na_2O)	.08
Potash (K_2O)	.12
Lime (CaO)	29.60
Magnesia (MgO)	17.43
Alumina (Al_2O_3) / Ferric oxide (Fe_2O_3)	1.30
Phosphorus pentoxide (P_2O_5)	.05
Silica (SiO_2) and insoluble	7.22
Undetermined	44.20
Total	100.00
Calcium carbonate ($CaCO_3$)	52.90
Magnesium carbonate ($MgCO_3$)	36.60
Total carbonates	89.50

This limestone is probably Chattahoochee, though no fossils were seen by which the age could be determined. The exposure has a thickness of 13 feet, with the river swamp at the foot. The overburden reaches a thickness of 18 feet some 150 feet back from the exposure. The limestone can be traced for about one-fourth mile along the escarpment.

The distance of this deposit from a railroad and the comparatively small quantity under a light overburden eliminates the deposit from being of commercial importance, except probably for local use

THOMAS COUNTY

The limestone exposures of Thomas County are confined to that portion south of an east and west line through Thomasville. In this section the Chattahoochee formation outcrops along the main streams and in several sinks. The northern part of the county is covered mostly by sandy loams of the Altamaha formation.

Within the terrane of the Chattahoochee and Alum Bluff formations the land is usually rather rough, with low hills and narrow valleys.

McKinnon Property (map locality Ts-1).—An exposure of magnesian limestone occurs on the M. D. McKinnon property, 5 miles east of Thomasville, one-fourth mile south of the 5-mile post on the Boston road and one-fourth mile north of the 5-mile post on the Atlantic Coast Line Railroad, in a broad piney woods area.

The stone is a hard cream colored semi-crystalline variety which breaks rather easily with a conchoidal fracture. A sample of the stone taken from the 1-foot exposure shows the following analysis:

Analysis of Sample from McKinnon Property (Sample No. 81)

Soda (Na_2O)	.31
Potash (K_2O)	.35
Lime (CaO)	25.26
Magnesia (MgO)	14.95
Alumina (Al_2O_3) / Ferric oxide (Fe_2O_3)	2.00
Phosphorus pentoxide (P_2O_5)	.04
Silica (SiO_2) and insoluble	20.12
Undetermined	36.97
Total	100.00
Calcium carbonate ($CaCO_3$)	45.10
Magnesium carbonate ($MgCO_3$)	31.55
Total carbonates	76.65

No fossils were seen by which the age of this deposit could be determined, but it undoubtedly belongs to the Chattahoochee formation. The stone does not bear a striking resemblance to any seen in this formation except in this immediate vicinity and near Faceville.

The exposure is flat, covering an area about 30 feet square in and level with a piney woods area of upwards of 100 acres, which slopes slightly to the south. The extent of the deposit and the thickness of the overburden could not be determined.

Before the advent of railroads in this section this stone was quarried and burned for building purposes. The old workings are now filled with talus so that the quantity of stone removed could not be estimated. The remains of the old kiln are still visible.

The analysis shows a rather siliceous limestone, but it is probable that better material underlies the outcrop. The stone is of sufficient hardness to be used for railroad ballast and concrete aggregate.

Mitchell Property (map locality Ts-2).—An exposure of medium-hard, grayish limestone, similar to the stone in the southern part of Grady County, was seen in the steep slope of an old limesink, 7 miles west of Thomasville and one-half mile north of the Thomasville-Boston public road, near the eastern boundary of the Mitchell property.

The exposure has a thickness of only 1 foot, occurring 30 feet above the bottom of the sink and 12 feet below the top of the slope. It belongs to the Chattahoochee formation. A sample of the partially weathered stone shows the following analysis:

Analysis of Sample from Mitchell Property, Thomas County (Sample No. 82)

Soda (Na_2O)	.04
Potash (K_2O)	.04
Lime (CaO)	27.60
Magnesia (MgO)	16.67
Alumina (Al_2O_3) / Ferric oxide (Fe_2O_3)	1.60
Phosphorus pentoxide (P_2O_5)	.06
Silica (SiO_2) and insoluble	12.40
Undetermined	41.59
Total	100.00

Calcium carbonate ($CaCO_3$)	49.24
Magnesium carbonate ($MgCO_3$)	35.00
Total carbonates	84.24

This analysis shows a rather low-grade magnesian limestone, but it is probable that the bed underlying the one exposed is of better quality, which is the case in other localities throughout this section.

No definite idea of the extent of this deposit could be obtained, due to the very small exposure. It is probable, however, that prospecting would show a workable body.

Boston Phosphate Works (map locality Ts-3).—Exposures of hard cream colored, partly crystalline limestone were observed in the abandoned pits of the Boston Phosphate Works, 3 miles west of Boston on the Thomasville road. The stone occurs as several small peaks of apparently a very irregularly weathered limestone. These several pits are 6 to 12 feet deep in reddish sandy clay, in which small phosphate nodules occur. The limestone makes up a very small percentage of the material above the 12-foot level. A surface well, 100 yards west of the pits, exposed no limestone in a depth of 30 feet.

Analysis of Sample of Limestone from Boston Phosphate Works (Sample No. 80)

Soda (Na_2O)	.04
Potash (K_2O)	.02
Lime (CaO)	52.94
Magnesia (MgO)	.20
Alumina (Al_2O_3) / Ferric oxide (Fe_2O_3)	.50
Phosphorus pentoxide (P_2O_5)	.06
Silica (SiO_2) and insoluble	3.72
Undetermined	42.52
Total	100.00
Calcium carbonate ($CaCO_3$)	94.54
Magnesium carbonate ($MgCO_3$)	.42
Total carbonates	94.96

Wade Property (map locality Ts-4).—Limestone was observed on the Wade place, one-fourth mile east of the Thomasville-Springhill road, 5¾ miles south of Thomasville. The stone is the hard, grayish variety seen at numerous localities southwest of this point, and in Grady County. The outcrop has a thickness of about 10 feet above the water level in a long narrow limesink with high steep sides. A small stream flows into this lake from the east, but there is no visible outlet.

R. G. Mitchell Place (map locality Ts-5).—On the R. G. Mitchell place, one-half mile west of the Thomasville-Springhill road, 7½ miles south of Thomasville, a few fragments of hard, grayish, magnesian limestone were seen scattered around the site of an old lime kiln in a gently sloping piney woods area. There was no exposure in place, so that it could not be determined whether the stone was hauled there to be burned or was quarried in the immediate vicinity. The latter is more probable, since a similar stone outcrops about 2 miles north of this exposure at a slightly lower level (see description Ts-7), and there seems to be no reason why the stone should be burned away from the source of supply.

A sample from these loose fragments shows the following analysis:

Analysis of Sample from R. G. Mitchell Place
(Sample No. 91)

Soda (Na_2O)	.06
Potash (K_2O)	.04
Lime (CaO)	28.32
Magnesia (MgO)	17.30
Alumina (Al_2O_3) / Ferric oxide (Fe_2O_3)	1.20
Phosphorus pentoxide (P_2O_5)	trace
Silica (SiO_2) and insoluble	10.59
Undetermined	42.49
Total	100.00
Calcium carbonate ($CaCO_3$)	50.44
Magnesium carbonate ($MgCO_3$)	36.30
Total carbonates	86.74

W. T. Madrea Property (map locality Ts-6).—A few water-worn fragments of medium hard, white, granular limestone were observed on the gentle slope of a hill on the W. T. Madrea place, 7 miles southwest of Boston, on the Monticello road. A large silicified coral and loose fragments of flint and ferruginous sandstone were also seen.

Original Pond (map locality Ts-7).—At the western end of Original Pond, 11 miles south of Thomasville and 4 miles west of Metcalf, the following section was observed:

Section at Original Pond

	Feet
4. Concealed	30
Chattahoochee formation.	
3. Brecciated, hard, white, porous limestone, with soft matrix	1
2. Soft, white, porous limestone	10(?)
1. Medium hard, white, fossiliferous limestone with thin, harder layers	10(?)
	51

A sample of the upper part of beds 1 and 2 at 1-foot intervals shows the following analysis:

Analysis of Sample from Original Pond (Sample No. 79)

Soda (Na_2O)	.23
Potash (K_2O)	.18
Lime (CaO)	51.00
Magnesia (MgO)	.61
Alumina (Al_2O_3) / Ferric oxide (Fe_2O_3)	.48
Phosphorus pentoxide (P_2O_5)	.05
Silica (SiO_2) and insoluble	6.03
Undetermined	41.42
Total	100.00
Calcium carbonate ($CaCO_3$)	91.00
Magnesium carbonate ($MgCO_3$)	1.25
Total carbonates	92.25

Original Pond is a clear lake covering about 6 acres in the lowest part of a large limesink covering about 100 acres, 50 feet below the surrounding country.

This deposit is of no great importance, due to the apparently heavy overburden and distance from transportation. There is, however, probably sufficient limestone along the edge of the slope to supply a small local demand.

A. H. Hough Place (map locality Ts-8).—Limestone is exposed on the A. H. Hough place, 11½ miles southwest of Thomasville, near the Springhill road on the gentle slope of a hillside. The stone is a medium hard, whitish variety with poorly preserved Pecten, Orbitoides, a large Gastropod, and other fossils. The horizon is probably Chattahoochee. A sample from loose boulders of the stone shows the following analysis:

Analysis of Limestone from A. H. Hough Place, Thomas County (Sample No. 92)

Soda (Na_2O)	.10
Potash (K_2O)	.08
Lime (CaO)	44.34
Magnesia (MgO)	5.13
Alumina (Al_2O_3) / Ferric oxide (Fe_2O_3)	1.00
Phosphorus pentoxide (P_2O_5)	.06
Silica (SiO_2) and insoluble	8.15
Undetermined	41.14
Total	100.00
Calcium carbonate ($CaCO_3$)	79.14
Magnesium carbonate ($MgCO_3$)	10.76
Total carbonates	89.90

The most of the limestone of this exposure occurs as loose boulders, but it also occurs in place in small sharp peaks which indicates a possible unconformity between the limestone and the overlying red and mottled sandy clay, but may be due to irregular weathering.

The exposure has a vertical extent of about 16 feet with the overburden gradually attaining a thickness of 25 feet. The quantity here with light overburden is apparently quite sufficient for local use.

BROOKS COUNTY

The most of the surface of Brooks County is covered by sands and clays of the Altamaha formation, but Alum Bluff strata outcrop along the principal streams and the Chattahoochee formation is exposed along the lower part of the Withlacoochee River, on the eastern border of the county. The limestone exposures are confined to the latter district and near the bottom of a few limesinks scattered over the county.

Devils Hopper (map locality Br-1).—Excellent exposures of the Alum Bluff and Chattahoochee strata occur on the G. W. Halloway property, lot 447, 13th district, 2 miles northeast of Barwick. There is here a large irregular limesink, some 60 feet deep, in a flat piney woods area. In the lower part of the sink, an opening to an underground channel, limestone is exposed, while above and in the gullies cut by two wet-weather streams which flow into the sink, sands and clays outcrop. This locality was described by McCallie[1] in 1896, but the succession of strata was not given. The following section is descriptive of the different beds of the exposure:

Section at Devils Hopper, Brooks County

	Feet
8. Sandy loam	1
Alum Bluff.	
7. Bluish, fullers earth-like clay (slightly arenaceous) with 6-inch bed of yellow sand about midway	15
6. Greenish, argillaceous sand, similar to that seen in Beasley limesink	10
5. Concealed (probably greenish, arenaceous clay)	5

[1] McCallie, S. W., Phosphates and Marls of Georgia: Bull. Ga. Geol. Survey. No. 5, 1896, p. 70.

Chattahoochee.

4. Hard, cream colored, compact limestone, weathers to a brown, arenaceous material	8
3. Soft, white, argillaceous limestone with black veinlets, probably manganese; weathers to yellowish, argillaceous material	6
2. Medium hard, light cream colored, argillaceous limestone; weathered product, deep cream colored clay	3
1. Brownish, compact, hard limestone; similar to stone of bed 3 in the Water Falls sink; weathers to soft, yellow, arenaceous material; breaks easily	15

The contact of the Alum Bluff and Chattahoochee formations is placed in this section by comparing the lithologic character of the strata with those of other sections. Organic remains seem to be absent. Samples of the limestone strata, taken at 1-foot intervals, show the following analyses:

Analyses of Samples from Devils Hopper

Sample No.	84	85	86
Bed No.	1 & 2	3	4
Soda (Na_2O)	.03	.14	.16
Potash (K_2O)	.15	.16	.10
Lime (CaO)	25.88	17.82	24.26
Magnesia (MgO)	15.01	10.72	13.06
Alumina (Al_2O_3), Ferric oxide (Fe_2O_3)	3.14	2.52	6.44
Phosphorus pentoxide (P_2O_5)	.09	.03	.06
Silica (SiO_2) and insoluble	17.17	40.23	20.34
Undetermined	38.53	28.38	35.58
Total	100.00	100.00	100.00
Calcium carbonate ($CaCO_3$)	48.53	31.82	43.36
Magnesium carbonate ($MgCO_3$)	31.41	22.50	27.40
Total carbonates	79.94	54.32	70.76

The magnesian limestone here is covered by 30 feet of sands and clay except in the narrow channel of the streams and immediately adjacent to the mouth of the sink. This overburden, together with the poor quality of the stone, makes it of little value for commercial purposes. A limited quantity for local use could be worked rather cheaply.

Thomas Beasley Property (map locality Br-2).—On the Thomas Beasley place, 5 miles east-southeast of Boston, there is a large irregular limesink, about 35 feet deep, in the piney woods, one-half mile northwest of the Beasley residence. In the main part of the sink there are several boulders of hard, cream colored, semi-crystalline limestone and greenish indurated fullers earth, similar to that seen on the Bruce place, several miles south, and near the Withlacoochee River, south of Valdosta. On the west side of the sink several small fragments of soft, white limestone containing Pecten, Glycimeris and Orbitoides were seen.

Near the eastern end of the sink there occurs a 15-foot bed of greenish, arenaceous clay at the base, grading into greenish, argillaceous sand at the top. This underlies a 7-foot bed of reddish sandy clay, which is the upper bed.

J. I. Bruce Place (map locality Br-3).—On the J. I. Bruce place, 9 miles southeast of Boston, large boulders of indurated fullers earth were seen in a matrix of red sandy clay in the banks of a small branch below the site of an old grist mill. This is the same brecciated, greenish stone seen on the Beasley property and along Withlacoochee River. This locality was described by McCallie[1] in 1896, under the title of the "J. L. Cutler Property." He observed "underlying these flint boulders a light colored, compact limestone." This material was not visible at the time of the writer's visit.

The exact horizon from which this greenish, indurated fullers earth was derived has, as yet, not been definitely determined. From

[1] McCallie, S. W., Phosphates and Marls of Georgia: Bull. Ga. Geol. Survey, No. 5, 1896, p. 68.

the evidence at hand, however, it appears to be a local induration of the lower part of the greenish, arenaceous clay occurring at the base of the Alum Bluff formation.

J. W. Haddock Property (map locality Br-4).—Limestone is exposed on the J. W. Haddock property, lot 96, 15th district, 8½ miles south-southwest of Quitman, 300 yards east of the Quitman-Monticello road. The stone is hard, semi-crystalline, and contains Turritella remains. The following analysis shows the chemical character of the stone:

Analysis of Sample from J. W. Haddock Property (Sample No. 87)

Soda (Na_2O)	trace
Potash (K_2O)	trace
Lime (CaO)	49.74
Magnesia (MgO)	.81
Alumina (Al_2O_3) / Ferric oxide (Fe_2O_3)	.42
Phosphorus pentoxide (P_2O_5)	.02
Silica (SiO_2) and insoluble	9.58
Undetermined	39.43
Total	100.00
Calcium carbonate ($CaCO_3$)	88.84
Magnesium carbonate ($MgCO_3$)	1.70
Total carbonates	90.54

This outcrop is 4 feet thick and occurs 100 yards north of a lime-sink pond about midway between the top of the gently sloping hill and the pond. The hill reaches a height of 50 feet above the pond in a horizontal distance of 200 yards. The exposure occurs in a small pit from which the stone was taken at one time and burned for building purposes. There are other small exposures of lesser note, occurring on the adjoining land lots.[1]

[1] Op. cit., p. 74.

WITHLACOOCHEE RIVER

Along Withlacoochee River, the eastern boundary of Brooks County, there are numerous exposures of limestone of the Chattahoochee formation, from 10 miles above to the Florida line.

On the Robert Groover place, lot 77, 15th district, 3 miles above Rocky Ford bridge, 15 feet of greenish, sandy, calcareous clay is exposed. This material is lithologically similar to that occurring in the Beasley limesink, at Devils Hopper, and other localities. The base of this exposure is about 8 feet above the river. A few miles above this point limestone is exposed for a thickness of 4 or 5 feet above the river water. (See Geology of the Coastal Plain of Georgia, page 339.) This indicates that this stone underlies the above described bed.

Two miles above the Georgia and Florida Railway tressel there is a 6-foot exposure of medium hard, partly crystalline, cream colored limestone containing Turritella, Arca, 2 Gastropods, and other fossils. Eight feet of Pleistocene sand overlies the limestone.

Near the end of the Georgia and Florida Railway tressel there were seen several boulders of the greenish, indurated fullers earth described on preceding pages.

From 2 miles below the tressel to the Florida line the limestone exposures are quite frequent. The strata exposed are similar to that described above and are from 1 to 15 feet thick, overlain by white Pleistocene sands. The best exposure occurs on the Lowndes County side of the river 100 yards below the wagon bridge on the Valdosta-Ellaville road.

LOWNDES COUNTY

Lowndes County is mainly within the terrane of the Altamaha formation with Alum Bluff strata exposed along the main creeks and rivers throughout the county and the Chattahoochee limestone along the Withlacoochee River in the extreme southern portion of the county. River terrace sands of probable Pleistocene age cover a great portion of all of these formations. The northern portion of the county is rather rolling while the southern portion is flat piney woods.

Map locality L-1.—On the north side of the river, 2 miles below the Georgia and Florida Railroad tressel, there is a 10-foot exposure of Chattahoochee limestone at the base of a bluff 30 feet high. The bluff is so steep that the limestone could not be examined in detail. The overlying strata were concealed and could not be determined.

No other exposures were seen between this bluff and the wagon bridge, 1 mile below.

Map locality L-2.—A good exposure of limestone occurs in the north bank of the Withlacoochee River, 100 yards below the wagon bridge, 3 miles down-stream from the Georgia and Florida Railroad tressel. The following section is descriptive of the strata exposed:

Section on Withlacoochee River, 3 Miles below G. & F. Railroad Tressel

	Feet
Pleistocene.	
4. Loose, white sand	3-5
Chattahoochee formation.	
3. Badly weathered, apparently originally hard, partly crystalline limestone in softer matrix, probably breccia	6
2. Medium hard, very white, granular limestone	5
1. Hard, partly crystalline, cream colored limestone	4
	18-20

Bed 3 resembles very closely the breccia occurring at the top of the Chattahoochee formation in the several exposures in the northern part of Grady County.

A sample taken from the lower 12 feet of the exposures shows the following analysis:

Analysis of Limestone from Withlacoochee River, 3 Miles below Georgia and Florida Railroad tressel (Sample No. 89)

Soda (Na_2O)	trace
Potash (K_2O)	.00
Lime (CaO)	53.28
Magnesia (MgO)	.03
Alumina (Al_2O_3) Ferric oxide (Fe_2O_3)	.82
Phosphorus pentoxide (P_2O_5)	.00
Silica (SiO_2) and insoluble	2.68
Undetermined	43.19
Total	100.00
Calcium carbonate ($CaCO_3$)	97.10

The limestone of this exposure is the upper part of the Chattahoochee formation. The beds are dipping slightly to the southeast.

This exposure is continuous along the river for several hundred feet. The overburden is 3 to 5 feet which is probably an average for a level area which extends from 100 to several hundred feet back from the river.

The distance of this deposit from transportation and its nearness to the water prevent it from being of much commercial importance; however, it is well situated and the stone is of excellent quality for local agricultural purposes. It will also make a good grade of lime upon being calcined. The lower strata is of sufficient hardness and toughness to make a fair ballast and concrete aggregate.

ECHOLS COUNTY

The southern half of Echols County is underlain by the Alum Bluff formation while the northern part is within the terrane of the Altamaha. These formations are rarely exposed, being covered by several feet of sand. The surface of the county is flat with an occasional shallow pond, due probably to the caving in of the roof of limestone caverns beneath the surface. Allapaha River, the principal stream, traverses the county from north to south. The only good exposures of beds in place are confined to the banks of this river along which are excellent exposures of Alum Bluff and Chattahoochee strata above and below Statenville.

At a point 2¼ miles up-stream from the bridge at Statenville there is an 11-foot exposure of a dark blue fullers earth. Underlying the fullers earth there are sands which are exposed from 2 miles above to 1 mile below the bridge. The upper part of the sand stratum is regularly bedded coarse quartz sand. There are apparently several lenses of arenaceous limestone about 2 feet thick in the upper part. At one point about 1 mile above the bridge the limestone is uncovered over an area of about 100 feet square in the side of the river, the top of the shelf being only about 2 feet above the water.

Beginning just below this limestone shelf there is a bed of cross-bedded, coarse sand. This stratum looks to be thin-bedded, dipping north with an unconformity between it and the overlying beds and cutting the thin layers off almost horizontally. This bed is exposed to 1 mile below the bridge with occasional calcareous lenses and small nodules.

Beginning 1 mile below the bridge and continuing 4 miles down-stream limestone is exposed on both sides of the river almost continuously. The upper part of the limestone stratum is the hard brecciated material seen in the counties to the west—Lowndes, Brooks, Thomas, and Grady. Beneath this is a hard, dove colored, oölitic limestone with occasional large sand pockets. These pockets were probably subterranean stream channels and pools at one time, subsequently filled with sand.

The limestone exposed in the banks of the stream varies from a few inches to 18 feet in thickness and is covered by loose, whitish sand, except near the outcrops of the overlying cross-bedded sands. The river banks are usually about 25 feet high, swamps and low, wet hammocks being very rare.

The limestone stratum evidently belongs to the Chattahoochee formation while the cross-bedded sands and the fullers earth are of the Alum Bluff beds. The loose sand described as overburden on the limestone is probably of the Okefenokee or Satilla formation.

The following locality description is of the most representative exposure along the stream.

J. I. Peterson Place.—One of the best exposures of limestone along the Allapaha River in Echols County is on the property of J. I. Peterson, 3½ miles below the bridge at Statenville, on the west bank of the river. The stone here is hard, dove colored, oölitic limestone, the upper few feet of which seems to have been brecciated. At the lower end of the deposit there is a bed of grayish, argillaceous sand about 10 feet thick, while the upper end of the bed changes suddenly to limestone. The sand bed is exposed for about 50 feet and apparently occupies what was at one time a cavern that had been dissolved out by the underground waters and subsequently filled with sand.

Unconsolidated sand overlies the limestone for a thickness of 8 feet, which forms the surface of the broad level piney woods country so characteristic of this section of the State.

A sample taken from the vertical face of the limestone shows the following analysis:

Analysis of Sample from J. I. Peterson Place, Echols County (Sample No. 121)

Soda (Na_2O)	.36
Potash (K_2O)	.18
Lime (CaO)	27.66
Magnesia (MgO)	14.43
Alumina (Al_2O_3) / Ferric oxide (Fe_2O_3)	3.28
Phosphorus pentoxide (P_2O_5)	.70
Silica (SiO_2) and insoluble	15.32
Undetermined	38.07
Total	100.00
Calcium carbonate ($CaCO_3$)	49.50
Magnesium carbonate ($MgCO_3$)	30.30
Total carbonates	79.80

The lithology and the geographic and topographic position of this magnesian limestone indicates that it belongs to the Chattahoochee formation. No disturbance of the strata seems to have taken place. They are apparently dipping slightly to the south or south-southeast.

The limestone bluff is continuous along the river for several hundred feet ranging from 15 to 18 feet in height. It is overlain by 6 to 10 feet of loose sands, which form the overburden. The Statenville railroad is about 2 miles northeast of the deposit.

The above analysis shows a magnesian limestone low in combined carbonates, comparatively high in phosphorus and a noticeable percentage of potash. These together make the stone well suited for agricultural purposes. The low carbonate content will probably prevent its being shipped outside of a rather restricted territory. The stone is of sufficient hardness and strength to make a fair-grade crushed stone for highway foundations, ballast and concrete aggregate.

CHARLTON COUNTY

The eastern half of Charlton County is a flat, almost featureless, sandy plain, while the western half is covered by a part of the Okefenokee Swamp. Exposures of the strata beneath the superficial sands are confined largely to the banks of the Satilla and St. Marys rivers, both of which have cut their channels down to nearly sea level as far as 50 miles from the coast. The former stream is affected by tides to a few miles above Burnt Fort and the latter some distance above Traders Hill.

Exposures of thin strata of limestones and marls of the Charlton formation occur in the banks of the St. Marys River. None of these deposits are of sufficient extent to be of commercial importance except for local use. The following descriptions of exposures are from the report of Veatch and Stephenson, on Geology of the Coastal Plain of Georgia, pp. 392-400:

Schoolhouse Bluff (map locality Ch-1).—The following section is exposed at Schoolhouse Bluff, St. Marys River, 4 miles below the Georgia Southern and Florida Railway tressel.

Section at Schoolhouse Bluff

	Feet	In.
Pleistocene.		
7. Gray or white sand at top of bluff	4-5	
6. Orange colored, argillaceous sand with clay at base, and beneath the clay a thin line of small quartz pebbles	12-15	
Pliocene (?).		
Charlton formation.		
5. Greenish, fine grained, sticky clay	3	
4. Soft limestone, and siliceous, fossiliferous material with Ostracods and *Rangia cuneata*	1	
3. White, calcareous clay	3	
2. Hard, earthy, argillaceous limestone	0	4
1. Chalky, argillaceous limestone with small gastropods	2	6
	25-29	10

This section shows 14 feet of limestone under about 25 feet of overburden.

A similar exposure occurs at Rand Landing, 1 mile down-stream from the above section.

Nettles Landing (map locality Ch-2).—Six to 7 feet of limestone is exposed at the base of a 40-foot bluff near Nettles Landing, St. Marys River, 10 miles south of Folkston. The position of the limestone is such that it could not be worked economically except possibly for a very limited local use.

Three miles below the above exposures, near Sawpit Landing, there is an outcrop of 8 feet of calcareous clay and chalky limestone beneath 3 feet of stiff, greenish clay. This deposit could probably be worked economically for local agricultural use.

CAMDEN COUNTY

Camden County, in the southeastern corner of the State, is a low, flat area covered with Pleistocene sands and clays. As in Charlton County the best exposures of the materials beneath the superficial Pleistocene sands and clay occur in the branches of St. Marys and Satilla rivers. Limestone and marl are present in several of these outcrops, but the beds are usually too thin and the overburden too heavy to allow the economical exploitation of the deposits.

McCallie[1] mentions beds of limestone and marl a few inches to 2 feet thick on the Satilla River near Burnt Fort and several miles farther up-stream on the King plantation. The marls on the latter place are said to have been used for agricultural purposes with very satisfactory results.

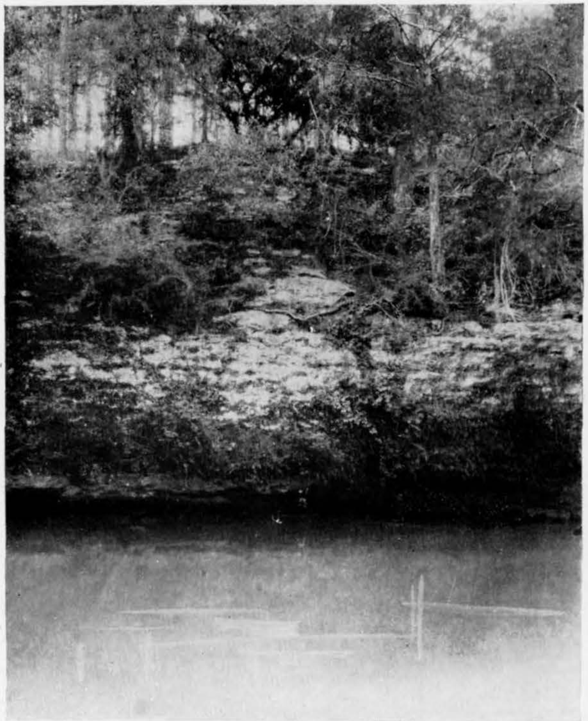
Other exposures are mentioned along White Oak Creek in the eastern part of the county. A marl deposit containing shells and fragments of bones is exposed at low tide beneath the railroad tressel near White Oak Station.

GLYNN COUNTY

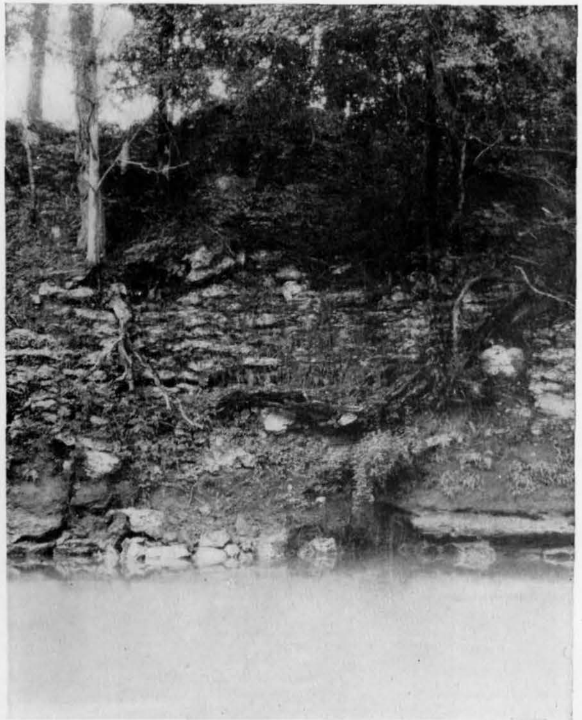
Glynn County is a low, flat, sandy area which differs but little in general appearance from the other counties along the coast of Georgia. The surface of the county is of thin beds of Pleistocene sands and clay. The only exposures of consequence of strata beneath the surface sands occur along the creeks and rivers. In a few of these outcrops there are thin beds of limestone and marl, few of which are workable on account of the thinness of the beds and the heavy overburden.

McCallie[2] mentions a thin bed of limestone exposed at low tide on College Creek, several miles west of Brunswick. Six feet of sandy, fossiliferous marl overlies the limestone. This latter material con-

[1] McCallie, S. W., Phosphates and Marls of Georgia: Bull. Ga. Geol. Survey, No. 5-A, 1896, pp. 86-89.
[2] Ibid., pp. 89-92.



A. LIMESTONE BLUFF, EAST SIDE KINCHAFOONEE CREEK, LEE COUNTY



B. LIMESTONE BLUFF, EAST SIDE KINCHAFOONEE CREEK, LEE COUNTY tains calcium carbonate and from one-half to 2 per cent phosphoric acid and should therefore be of considerable value for local agricultural uses. There are probably other exposures of this and similar materials that could be economically worked for local use.

OYSTER SHELLS

A possible small supply of calcium carbonate for agricultural and other uses may be obtained from oyster-shell piles which accumulate at canneries and along the shores of the mainland, islands and salt-water marshes along the coast of Georgia. There are canneries near Savannah, on St. Catherine Island, near Darien, and at Brunswick that produce from 250 to 1000 bushels of shells each per day for a period of 6 months out of the year. These "green" shells are at present used mainly in highway construction, but are also crushed to the size of cracked corn and sold to poultry raisers. They might be pulverized and sold to the agriculturists, but the quantity is small and the price received for the shells for other purposes is as much or more than could be realized when sold in the pulverized state.

There are occasional beaches along the coast that are covered with the so-called "dead" shells that have been washed up from the bottom of the bays and estuaries by the high spring tides. An excellent example of this type of deposit occurs on the shore of a salt-water marsh 3 miles west of St. Simons Light near Brunswick. The deposit is several hundred yards in length and at low tide is 75 feet wide with the top of the shell pile 14 feet above the water. The thickness of the bed could not be determined, but it is probably several feet. A number of these shell banks are visible at low tide between Brunswick and St. Simons and Jekyl islands.

There is a small plant near Brunswick that pulverizes the shells from these deposits for agricultural use. The shells are loaded from the banks upon lighters and then towed to the plant where they are re-handled to the pulverizer by shovel and wheelbarrow. This is a comparatively expensive operation, but where a good price can be obtained for the product the deposits can be profitably worked.

The following analysis is of a general sample from an oyster shell pile at the Atwood cannery at Valona, McIntosh County:

Analysis of "Green" Oyster Shells from Atwood Cannery (Sample No. 119)

Soda (Na_2O)	trace
Potash (K_2O)	trace
Lime (CaO)	53.04
Magnesia (MgO)	trace
Alumina (Al_2O_3) / Ferric oxide (Fe_2O_3)	.....
Phosphorus pentoxide (P_2O_5)	.04
Silica (SiO_2) and insoluble	4.02
Undetermined	42.90
Total	100.00
Calcium carbonate ($CaCO_3$)	94.64

Oyster shells are practically pure calcium carbonate. The silica and insoluble is the sand and mud which adheres to the shells.

PART III.

USES AND PREPARATION OF LIMESTONE

AGRICULTURAL USES OF LIMESTONE AND LIME

SOIL CORRECTIVE

The use of limestone and lime for soil improvement dates back some two thousand years. Later writings show that the practice was subsequently adopted in England, Germany, France, and other European countries. It was used in the United States at least as early as the latter part of the eighteenth century and probably before.

The primary object of applying limestone or lime is to correct by neutralization the acidity of the soil. All soils are not acid or "sour," nor do all crops thrive better on a "sweet" soil; hence, the use of the corrective should be governed by the soil under consideration and the crops which are to be planted therein. The limestone or lime also helps the physical condition of the soil and acts directly as a fertilizer when the soil is deficient in calcium.

The final and greatest value of limestone for the soil, the restoraation and increase of permanent fertility, is due to the combined effects of the various individual actions. Thus, by neutralizing the acids in the soil the legumes are capable of storing up larger quantities of nitrogen-forming humus, which supplies subsequent crops with nitrogen, as well as makes the soil more pulverulent and fallow and hence more retentive of plant food and the proper amount of moisture. The physical action of the limestone and lime on the different soils, which will be discussed later, likewise leads to the same end. By improving its physical condition the soil is also more responsive to cultivation and is more easily tilled.

PROPERTIES OF LIMESTONE

Limestone, marble, chalk, marl, and oyster shells are all calcium carbonates or lime carbonates containing impurities, usually sand and clay. The carbonate percentage may vary from a few per cent to practically 100 per cent. Experimental data seem to show that these varieties of lime carbonate have equal value for the uses to which they are put in agriculture. Dolomite, when pure, contains both magnesium and calcium carbonates in the ratio of 0.86 to 1. All authorities on the subject do not agree on the relative values of the calcium and magnesium carbonates; the concensus of opinion seems to be, however, that values are about equal, provided the stone contains considerably more calcium than magnesium. The chemical and physical activities of the two carbonates are practically the same, but probably slower in the case of the dolomite since it is less readily attacked by acids.

Chemical Action.—According to Hopkins the principal and, in most cases, the only justifiable reason for applying limestone or lime to the soil is to neutralize the acids contained therein, or to "sweeten" the "sour" soil. These acids are carbonic, nitric, lactic, acetic, and various others, derived principally from the decomposition and fermentation of organic matter.

Limestone is the product of the action of carbonic acid on lime thus:

$$H_2CO_3+CaO=CaCO_3 \text{ or } (CaO.CO_2)+H_2O \text{ (water)}$$

It is therefore a neutral salt. When this salt comes into contact with an acid it gives up its carbon dioxide (CO_2) and unites with or neutralizes the acid thus:

$$CaCO_3+2HNO_3 \text{(nitric acid)} = Ca(NO_3)_2 \text{(a neutral salt)} + CO_2 + H_2O$$

The reactions with other acids are similar.

Limestone also aids in breaking down organic matter, making the nitrogen more readily available. It is seen, then, that unless the supply of humus is replenished the soil will become exhausted of this matter. This action by the carbonate is very slow when compared to caustic lime.

When limestone is added to soils containing large amounts of insoluble phosphorus or potash salts it reacts slowly upon them, changing them into soluble plant food. Caustic lime has the same effect as limestone, but it acts more rapidly. This activity is doubted by some authorities, while experiments by others seem to bear it out. The latter being the case it is seen that the soil must be supplied with these fertilizers—phosphorus and potash—otherwise it will become depleted of the plant food and finally sink to a poorer state of fertility than if neither fertilizer nor limestone was used.[1] Hence the old adage "Lime enriches the father and impoverishes the son."

When phosphates are added to soils containing little calcium they have a tendency to unite with iron and aluminum into an unavailable form. If calcium is also present the phosphate reacts with it forming a slowly available plant food.

Calcium and magnesium are both plant foods, therefore limestone and dolomite have direct manurial value and should be added to all soils deficient in these constituents.

Physical Properties.—When limestone is applied to a tough clay-soil it tends to make it less plastic and more pulverulent, and hence more permeable and less apt to form hard clods upon drying out. On a sandy soil it has the opposite effect, holding the sand granules together and making it more retentive of moisture and plant food applied as fertilizers. The mechanical effects are said to become more evident as the limestone becomes more thoroughly mixed with the soil or after the continued use.

LIME

As stated on preceding pages, limestone or calcium carbonate is represented in chemistry by the symbol $CaCO_3$ or $CaO.CO_2$. When this material is heated to a temperature of about 900° C. the gas, carbon dioxide (CO_2), is driven off thus:

$$CaCO_3 + \text{heat} = CaO \text{ (lime) } + CO_2$$

The lime (CaO) is 56 per cent and the carbon dioxide (CO_2) 44 per cent of the weight of the calcium carbonate or pure limestone. There-

[1] It should be noted that the weathering of the underlying rocks is a perpetual source of supply of plant food.

fore, since lime or calcium oxide is the part of limestone which neutralizes the acids of the soil, 1120 pounds of lime is equivalent to 2000 pounds of pure limestone.

When lime is left in the air for a few days or weeks, according to the percentage of moisture in the atmosphere, it is seen to crumble to a fine powder. This is due to the water in the air entering into chemical combination with the lime forming calcium hydroxide ($Ca(OH)_2$), hydrated lime or air-slaked lime. This result may be accomplished more quickly by pouring water on the lime, as is the case when lime is slaked for making building mortars. By this action 1120 pounds of caustic lime yields 1480 pounds of hydrated or slaked lime. The lime or calcium oxide is the active constituent in neutralizing acids. Hence one ton of pure limestone when applied to the soil will have the same value as 1120 pounds of lime or 1480 pounds of slaked lime.

When lime is left in the air for a considerable length of time it will absorb carbon dioxide from the air and revert to the original composition of the limestone from which it was derived. The same action takes place in the soil. Hence, whether limestone, lime or slaked lime is applied there will in the course of time be limestone in the soil.

Chemical and Physical Action.—The action of limestone and lime in the neutralization of the soil acids is the same, but the action of caustic lime on the humus or organic matter is much more rapid and violent. When the lime comes in contact with the decaying vegetable matter it hastens the action by tearing down the cells or "burning" and in this way releasing a large proportion of the valuable nitrogen contained therein. Care should be taken then to return to the soil that quantity of humus destroyed by the lime unless the land is unusually rich in organic matter, such as swamp or peat lands.

If the soil is deficient in calcium or magnesium for plant food the limestone and lime have the same value, proportionately to the percentage of lime and magnesia in the limestone.

The physical action of the lime on the soil is similar to the action of the limestone, which has been mentioned in a preceding paragraph.

From the above statement it is seen that the action of limestone and lime when applied to the soil is practically the same except that the latter tends to destroy the valuable humus. The results of the experiments by the various State Agricultural Experiment Stations in the North and South seem to indicate that the limestone gives slightly better results than the caustic or hydrated lime. However, the difference is so slight that the material to be used should be governed by the cost, remembering that 1120 pounds of lime is equal in value to 1480 pounds of slaked lime or 2000 pounds of limestone. Since these materials vary widely in purity the approximate analysis should be known by the buyer and purchased on the basis of the calcium and magnesium content.

In order to determine the availability for plant food of the potash and phosphoric acid of limestone, three similar tests were made. Three limestone samples obtained in South Georgia were selected and 100 grams of pulverized stone weighed out from each, which were placed in separate tin cans with 3 liters of distilled water. Carbon dioxide was then passed into the water to make it as similar as possible to meteoric water. The carbonated water remained on the limestone for 3 months, the cans being well shaken each day for the first month.

At the end of the third month the water was analyzed with the following results:

Analyses for Solubility of Potash and Phosphoric Acid of Limestone

Sample No.	6		57		84	
Analysis of	Limestone sample	Soluble in water	Limestone sample	Soluble in water	Limestone sample	Soluble in water
Soda (Na_2O)	.22		trace		.03	
Potash (K_2O)	.38	.0084	.06	.003	.15	.009
Lime (CaO)	52.98		47.62		25.88	
Magnesia (MgO)	.22		.32		15.01	
Alumina (Al_2O_3), Ferric oxide (Fe_2O_3)	1.00		1.26		3.14	
Phosphorus pentoxide (P_2O_5)	.10	trace	.56	trace	.09	trace
Silica (SiO_2) and insoluble	2.84		6.78		17.17	
Undetermined	42.26		43.40		38.53	
Total	100.00		100.00		100.00	

These results show that 2.2 per cent of the potash of sample No. 6 was soluble, 5 per cent of sample No. 57, and 6 per cent of sample No. 84. The phosphoric acid was only slightly soluble.

VALUE OF LIMESTONE AND LIME FOR AGRICULTURAL PURPOSES

The first thing to be taken into consideration when the use of limestone or lime is contemplated is the crops to be grown. Certain plants grow best on a slightly acid or sour soil, while others require a neutral or sweet soil. In the first group are such plants as cotton, peanuts and watermelons; in the second, all of the leguminous plants, grains, grasses and most vegetables. Some experts include cotton and peanuts in the list of the benefited plants, leaving watermelons as one of the few plants that are injured. The vines of this last named plant grow very luxuriantly under limed conditions but the fruit is small and unsound.

Experiments and practice show that alfalfa, the clovers, and other legumes are practically always failures when seeded in an even slightly acid soil. The nitrogen gathering bacteria of these legumes can only develop properly in sweet soils, consequently in sour soils such plants do not have the power they should have to collect atmospheric nitrogen by means of the root-tubercle bacteria. Hence, their value as soil enrichers as well as the proper yield of the crop itself is lost unless limestone is used or the soil is already sweet.

Experiments with wheat, oats, rye, corn, etc., show a varying increase in yield when seeded in a limed soil. Certain authorities state that caustic lime prevents "rust" or "smut" on these plants. A majority of truck or vegetable plants yield more abundantly on a sweet or neutral soil, while others are but little affected by the use of lime. Under the former are such crops as beets, cantaloupes, cucumbers, squash, tomatoes, peppers, etc., and under the latter, potatoes, egg plant, etc. Experiments by the Rhode Island Agricultural Experiment Station indicate that lime is very valuable for pasture and hay grasses and a detriment to the common weeds.

A notable fact about the limestone ridges of the Coastal Plain of Georgia is that they are almost without exception covered with an abundant growth of such hard woods as the oak and the hickory and the haws, crabapple, red bud, and other plants. The absence of pine, especially long-leaf, is very noticeable. Hence, we conclude that the species of the first group desire a sweet soil, while the pines grow more favorably on sour land. Experiments, according to information received direct from several agriculturists in South Georgia, indicate that the growth of pecan trees is greatly increased by the use of limestone. This is borne out by the selection of the limestone soils by the hickory which is very closely related to the pecan.

After the crop desired is known it should be determined whether or not the soil is in need of a neutralizing agent. Since calcium carbonate is soluble to a slight extent in meteoric waters it is leached out of the top soil and carried downward. This, together with the action of humic acids on the lime and that taken up by plants, causes the large majority of soils to lack sufficient alkalies to maintain a neutral condition of the soil. In the following table partial analyses are given of several types of soil in the Coastal Plain area of Georgia:

Partial Analyses of South Georgia Soils

(Analyses by Chemical Department of the Georgia Department of Agriculture)

Sample No.	Type of soil	Total Phosphoric acid	Potash	Acidity
1	Sand-clay	.14	.12	Neutral
2	Sandy	.04	.06	Acid
3	Sandy	.06	.05	Acid
4	Clay-sand	.04	.05	Acid
5	Clay subsoil	.12	.06	Acid
6	Sandy	.04	.06	Slightly Acid
7	Clayey	.56	.05	Acid
8	Sandy	.10	.06	Acid
9	Sandy	.06	.04	Acid
10	Clayey	.06	.05	Acid
11	Sandy	.08	.05	Acid
12	Sandy	.08	.10	Acid
13	Sandy	.08	(a)	Acid
14	Clay-sand	.10	(a)	Acid

Description of Samples

1. Pebbly, yellow, sand-clay soil. One-half mile south of railroad station, Tennille, Washington County.
2. Sandy soil. One-fourth mile north of courthouse, Homerville, Clinch County.
3. Dark gray, sandy soil, from bottom land, 8 miles north of Valdosta, Lowndes County.
4. Brown, pebbly, clay-sand soil, 2 miles north of Valdosta, Lowndes County.
5. Brown, pebbly soil, yellow clay subsoil, 1 mile west of Quitman, Brooks County. Good crop of cotton on land.
6. Sandy soil from between Blue Spring and the Withlacoochee River, Brooks County.
7. Yellow, clay-soil from near old Toy Phosphate pits, 3½ miles west of Boston, Thomas County.
8. Sandy soil from 1 mile north of Thomasville, Thomas County.
9. Sandy soil from near Pine Park, Grady County.
10. Pebbly, clay-soil from 2 miles north of Whigham, Grady County.

11. Sandy soil from 2 miles west of Faceville, Decatur County. A poor crop of corn and peanuts on land.
12. Dark gray, sandy soil from 6 miles west of Bainbridge, Decatur County.
13. Sandy soil, Abbeville, Wilcox County.
14. Clay-sand soil, Preston, Webster County, 250 yards northeast of courthouse.

Of the 14 samples analyzed, 1 is neutral, 1 slightly acid and the remaining 12 acid. Therefore, 13 out of the 14 soils are in need of some neutralizing agent. Limestone is the cheapest and most effective material that can be used. The phosphoric acid percentages show the total in the soil, while the potash given is that soluble in a 20 per cent solution of hydrochloric acid. The potash in the feldspar, mica, etc., of the soil is not shown.

A total of 25 or 30 samples of several types of soil from Twiggs, Bleckley and Jefferson counties were tested with litmus paper by the writer. All samples proved to be acid with the exception of 4, which were secured from a bottom at the foot of a limestone ridge.

These results tend to show that the large majority of the soils of South Georgia are acid and, therefore, in need of lime or limestone. The quantity of the neutralizer to apply depends upon the acidity of the soil and the crops to be grown.

A natural indicator of acidity is the common sour grass, which according to certain authorities, grows only on sour land. A simple test of the soil may be conducted as follows: Secure from a druggist a bottle of fresh blue litmus paper. To take a sample of soil, dig a hole about 6 inches deep and take from it a tablespoon of dirt 2, 4, and 6 inches below the surface, using a clean spoon. Put the material thus obtained in a clean bowl or cup and mix to a thin paste with rain water, melted ice, or distilled water obtained from a druggist. Take a strip of the litmus paper and insert one end in the paste, allowing it to remain about 30 minutes. Care should be taken that the fingers do not touch the part of the paper put in the paste. Remove and rinse in the pure water. If the color has changed to a decided pink the soil is very sour; if only a pinkish tint is noticed the soil is only slightly acid, if no change takes place the soil is neutral. There is an instrument made by the Standard Soil Tester Company, of Milwaukee, Wis., for testing soils for calcium carbonate. It is so calibrated that it reads directly the number of thousand pounds of calcium carbonate contained in a plowed acre. The principal is the displacement of water by carbon dioxide derived from a certain weight of soil by the action of hydrochloric (muriatic) acid. The instrument has never been tested by the writer, but is highly recommended by a number of agricultural demonstrators and agricultural school instructors. To test an acre, if the soil is uniform, a sample should be secured from each corner and one from the center. Knowing the quantity of calcium carbonate in the soil and the quantity there should be for the best results the quantity to be applied is readily computed.

A more accurate test may be had by sending a sample of the soil to a chemist to be analyzed. One author says:[1] "...Any soil containing less than 1 per cent of calcium carbonate will be benefited by liming, and when the percentage falls to one-fifth per cent lime becomes a necessity to enable the manures to exert their proper action."

QUANTITY OF LIMESTONE TO APPLY

One ton of ground limestone per acre or the equivalent weight of caustic lime or hydrated lime, is usually sufficient to neutralize the acidity of most soils. To obtain the best results, however, a larger quantity should be added in order to have a reserve supply in the soil to neutralize any acids that may develop subsequent to the first application. The best practice seems to be to apply 2 or 3 tons of ground limestone per acre first and then about 1 ton per acre every four or five years thereafter. This quantity is sufficient to supply that neutralized by acids, removed by the plants, and carried off by leaching.

PREPARATION OF SOIL AND WHEN TO APPLY LIME

The soil to be limed should first be broken up and harrowed, the ground limestone or lime then spread and harrowed in. The more

[1] Hall, A. D., Fertilizers and Manures, 1910, p. 253.

closely the lime is incorporated with the soil the better the results. Since the tendency of the lime is always to go downward it should never be turned under with a plow.

Although limestone can be applied at any time during the year with beneficial results, it should be applied several months previous to the preparation of the seed bed for a leguminous crop such as peas or clover. If the legume is to follow oats or wheat the limestone should be applied to the seed bed for the grain crop in the Fall, as early before the sowing or drilling as possible. Neither limestone nor lime, especially the latter, should ever be drilled in with the seed. In the first case its effectiveness in reaching all parts of the soil is materially decreased, in the second the caustic lime is apt to destroy the life of the seed. Limestone should never be mixed with fertilizer or manures or used in their place. The land should be limed as needed and the fertilizer then used without regard to the liming.

METHODS OF APPLYING

In applying 2 tons of ground limestone per acre, piles containing 80 pounds should be placed 30 feet apart over the area. From these piles the material may be easily spread by means of a shovel. If a large area is to be treated it would probably be more economical to purchase a spreader constructed for that purpose. Several agricultural implement manufacturers have these machines on the market. A very efficient spreader is described by C. E. Thorne[1] as follows:

> Make a hopper similar to that of an ordinary grain drill, except that it should be 8 feet long with sides and top 18 to 24 inches wide. Let the bottom be 5 inches wide in the clear and cut in it a row of oval holes, 1 inch wide, 2 inches long and 8 inches apart. Make a false bottom with holes in it of the same size and shape as those of the main bottom, and so spaced that they will register. Let this false bottom slide loosely under the hopper, moving upon supports made by leaving a space for it above bands of strap iron, which should be carried around the hopper every 2 feet to strengthen it. Both bottom pieces should be of smooth, seasoned hardwood, seven-eighths inch thick and well oiled or painted. To the lower strip rivet a V-shaped arm, extending an inch in front of the hopper, with a half inch hole in the point of the V, in which drop the end of a strong lever, bolting the lever

[1] Thorne, C. E., The Maintenance of Fertility (Liming the Land): Bull. Ohio Agri. Exp. Sta., No. 279, July, 1914, p. 23.

loosely but securely to the side of the hopper, 3 or 4 inches above the bottom. Let the lever extend 6 or 8 inches above the top of the hopper, and fasten to the side of the hopper a guide of strap iron, in which the lever may move freely back and forth. The object of this lever is to regulate the size of the openings by moving the bottom plate. Make a frame for the hopper, with a tongue to it, similar to the frame of an ordinary grain drill.

Get a pair of old mowing machine wheels, with ratchets in the hubs, and two pieces of round axle of sufficient length to pass through the wheels and frame and into the ends of the hopper, where they are welded to a bar of iron 1¼ inch in diameter and the length of the inside of the hopper. The axles should be fitted with journals, bolted to the underside of the frame.

Make a reel to work inside of the hopper by securing 8 short arms of one-fourth inch by three-fourths inch iron to the axle, and fastening to these 4 beaters or wings of three-eighths inch by five-eighths inch iron, and about an inch shorter than the inside of the hopper, the reel being so adjusted that the wings will almost scrape the bottom of the hopper but will revolve freely between the sides. These arms should be made of 2 pieces, bent so as to fit around the axle on opposite sides, and secured by small bolts passing through the ends and through the beater which is held between them. The diameter of the completed reel is about 5 inches and its length an inch or so less than that of the inside of the hopper. This reel serves as a force feed.

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INSECTICIDES AND FUNGICIDES

Lime is used in the preparation of a number of solutions and powders to be sprayed or dusted on vegetation to destroy insects and fungi. Calcium oxide is the only useful constituent of the lime and hence impurities, such as magnesia, alumina, etc., act as adulterants. For this use the lime must be free from sand grains or other coarse particles, otherwise the solution will not go through the sprayer nozzle or duster.

The following are some of the more important insecticides and fungicides in which lime enters as one of the main ingredients: Paris green solution, lime-sulphur wash, and Bordeaux mixture.

CRUSHED LIMESTONE

Concrete Aggregate.—Crushed limestone is used very extensively in certain sections of the country as the coarse aggregate for concrete. The requirements are that the stone shall be hard, tough, and have a high crushing strength. The size of the aggregate depends largely upon the purpose for which the concrete is used. In ordinary street or foundation work, stone that will all pass a 2½ inch and rest on a one-half inch ring is used. In monolithic concrete construction the aggregate may be somewhat coarser while stones weighing several tons are placed in the concrete in such a way that they will not touch. There are certain deposits of limestone in South Georgia that would furnish a good grade of stone for concrete work though not being of equal value to the harder stone of North Georgia. These deposits are in the Midway, Ocala and Chattahoochee formations in Macon, Randolph, Clay, Calhoun, Lee and Worth counties and the counties along the Georgia-Florida State line, west of Echols County.

Road Metal.—Crushed limestone is used in road construction for foundation and surfacing material. The requirements are similar to those for concrete aggregate. The crushed stone that will all pass a 2½ inch ring with the fines screened out is used for the foundation material. A bituminous or other type of binder may then be used or the fine stone spread over the top and worked down to fill the voids among the coarser stone. Limestone has the advantage over other types of stone of having relatively high cementing properties.

Ballast.—For railroad ballasting material a stone that has high crushing strength, and will neither chip nor dust easily is required. The stone crushed to a size that will pass a 2½ inch and rest on a one-half inch ring is most commonly used. It is spread along the road bed over the cross-ties and then tamped beneath the ties with shovels or especially made tools, hence the necessity for a tough stone. Some of the stones listed under "Concrete aggregate," above, will furnish a fair grade of material for this work.

MORTAR

By far the most important use of lime is in making ordinary building mortar. The variety of lime that should be used depends largely upon the experience of the mixers and the cost, as well as the properties of the lime itself. A laborer who has been accustomed to working with a "hot" or quick-slaking lime will probably not be able to get the best results with a "cold" or slow-slaking variety. The location of the construction work with reference to the place of manufacture of the different limes will govern the cost.

There are three properties of the lime to be taken into consideration, namely, the volume of mortar it will produce, the workability of the mortar, and the final strength. High-calcium limes, containing not more than 5 per cent of impurities, not including magnesia, will here be considered.

A high-calcium lime slakes rapidly and evolves much heat. If properly prepared it will yield a larger volume of paste than the low-calcium limes; but on the other hand, if it is allowed to burn while slaking the volume will be materially decreased. The paste is sticky which, together with the increased volume, means that a large quantity of sand can be used in the final mortar.

High-magnesian or dolomitic limes slake slowly and evolve much less heat than the high-calcium limes and thereby lessen the danger of burning. They likewise yield a smaller volume of paste, which is less plastic and as a consequence produce a smaller volume of mortar. In setting, the shrinkage of magnesian-lime mortar is much less than mortars made from high-calcium limes.

From the brick mason's point of view the high-magnesian limes are the more desirable, since they are not so sticky and hence more easily troweled; furthermore, they set more slowly, which allows him to spread a larger area with mortar before placing the brick. On the other hand, however, high-calcium limes are preferred by the contractor, because they yield a larger volume of mortar and harden more rapidly, enabling him to complete the work sooner.

Magnesian limes are said to yield the stronger mortars, but since the pressure to which they are subjected in a brick wall or other structure is comparatively small the relative strength need not be considered for ordinary work.

Hydrated lime is taking the place of caustic lime, to some extent, in making mortar. By using the former the danger of burning is eliminated, also a more efficient mortar is assured since all of the inert lumps are screened out subsequent to the hydration by the manufacturer. The cost is, of course, somewhat greater than for lump lime, but this is largely offset by the saving of the expense of slaking and seasoning.

The hardening of a mortar is due to the combination of the carbon dioxide of the air with the lime of the mortar, thus forming limestone or calcium carbonate, which is similar in composition to the stone from which the lime was originally derived. The outer surface of the mortar takes up the carbon dioxide first which seals the pores, more or less, and prevents the inner part of the mortar from hardening.

PLASTER

Lime to be used for plastering must fill several requirements—it must not "pit" or "pop," must work smoothly under the trowel, and the shrinkage due to setting should be as little as possible. If the lime is to be used for the finish coat it should be white, or nearly so.

"Popping" or "pitting" seems to be due to impurities in the lime which form chemical combinations with the calcium and slake very slowly. This slaking may take place partly after the plaster has been spread and since expansion takes place a soft spot will develop from which the material will eventually fall out, leaving a pit. Particles of lime burned during slaking will likewise hydrate slowly and, therefore, may cause pits. There is less danger of burning magnesian limes than high-calcium limes during the hydration process.

Magnesian limes yield a plaster that is more easily spread than that made from high-calcium limes, the latter, however, will yield a larger volume and hence cover a larger surface.

The shrinkage of magnesian lime plasters due to setting is less than that of high-calcium limes, hence cracks are more liable to develop when the latter is used. The cracking, however, may be largely overcome by the use of hair, wood fiber, or some similar material. For the finish coat magnesian limes are to be preferred since they are generally more nearly white.

Hydrated lime may be used in the place of lump lime for plastering. It is generally more pure than lump lime and hence should give better results.

USE OF HYDRATED LIME WITH PORTLAND CEMENT

Hydrated lime is used to some extent with Portland cement for two purposes—to increase the workability of the cement mortar and to decrease the porosity.

Cement mortars have little or no plasticity and hence their working quality is poor. It has been found that the addition of 5 to 15 per cent of hydrated lime will make the mortar more responsive to the trowel without materially injuring the hydraulicity or strength of the cement. Also, the hydrated lime is more finely divided than the cement and will, therefore, occupy the space between the cement particles. In this way the hardened mortar is made more impervious to water.

HYDRAULIC CEMENTS

It was mentioned under the head of "lime manufacture" that when the temperature of the lime kiln is 1200° C. or over, a chemical combination takes place between the lime and its impurities such as silica, ferric oxide and alumina. This material will set under water, and is known as hydraulic cement. The setting is caused by the crystallization of the silicates and aluminates of lime.

There are several varieties of hydraulic cements, such as, Puzzolan cement, hydraulic lime, natural cement, and Portland cement.

Puzzolan cement consists of a mixture of slaked lime and blast furnace slag or volcanic ash.

Hydraulic lime is formed by burning siliceous or argillaceous limestone at a temperature slightly above that of decarbonization. Under these conditions silicates, aluminates and ferrites of lime are formed. There must be enough of the calcium silicate present to cause the burned limestone to set under water and also enough free lime to cause the lumps to slake upon the addition of water.

The following table[1] has been prepared by Eckel as representing the ideal composition of hydraulic lime.

Composition of Ideal Hydraulic Limestone and Hydraulic Lime (Eckel)

	Hydraulic limestone before burning	Hydraulic lime	
		Before slaking	After slaking
Silica (SiO_2)	13.20	21.20	19.08
Lime (CaO) ..	86.80	78.80	70.92
Carbon dioxide (CO_2)		0.00	0.00
Water (H_2O)	0.00	0.00	10.00
Total	100.00	100.00	100.00

This exact composition is rarely if ever found in a limestone as iron and alumina are practically always present. In the following

[1] Eckel, E. C., Cements, Limes and Plasters, 1905, p. 175.

table[1] analyses of limestones of Europe used for the manufacture of hydraulic limes are given:

Analyses of Hydraulic Lime Rock (Ries)

	1	2	3	4
Silica (SiO_2)	14.30	11.03	7.60	17.00
Alumina (Al_2O_3)	.70	3.75	.75	1.00
Iron oxide (Fe_2O_3)	.80	5.07		
Lime (CaO)	46.50	43.02	50.05	44.80
Magnesia (MgO)	Undet	1.34	.30	.71
Carbon dioxide (CO_2)	36.54	35.27	41.30	35.99
Water (H_2O)	.....	.....		
Total	98.84	99.48	100.00	99.50

1, Teil, France; 2, Haurenbergen, Germany; 3, Malain, France; 4, Senonches, France.

The silica content must, of course, be in very finely divided particles or in clay, otherwise, the combination with the lime will be incomplete. Magnesia acts the same as lime, molecule for molecule, taking into consideration, of course, the respective atomic weights. There are a great many limestones in South Georgia approximating the above analyses, but in the majority the silica occurs as rather coarse sand grains. The analyses given below are of stones suitable for the manufacture of hydraulic limes.

Analyses Hydraulic Limestones

Sample No.	13	59
Silica (SiO_2)	11.20	11.33
Lime (CaO)	46.76	48.04
Magnesia (MgO)	trace	.36
Alumina (Al_2O_3) / Ferric oxide (Fe_2O_3)	2.06	2.56
Carbon dioxide (CO_2)	36.75	37.70
Water (H_2O) (approx.)	2.50	.....
Total	99.27	99.99

No 13, from Colliers Bluff, Ocmulgee River, 5 miles above Hawkinsville.
No. 59, from mouth of Cedar Creek, Flint River.

[1] Ries, H., Economic Geology, 1910, p. 141.

Hydraulic lime is burned in the same type of kiln as is used in the manufacture of ordinary lime. After burning, it is slaked by adding just enough water to hydrate the free lime. Its advantage over quick lime is its ability to set under water, a property less marked than in Portland cement.

Little or no hydraulic lime is manufactured in the United States at present, but it is much used in Europe. A small quantity is imported by this country and sold under the name of "Lafarge."

Natural cement is the oldest of that group of cements possessing hydraulic properties. It was manufactured and used by the early Egyptians, Greeks, and Romans for purposes which required a mortar that would set or harden under water. The industry, although of great importance in the European countries, has been largely replaced in the United States by Portland cement.

Natural cements are manufactured by burning argillaceous limestone containing 15 to 35 per cent clayey material, of which 10 to 25 per cent is silica and 5 to 15 per cent alumina and ferric oxide. Magnesia may take the place of about two-fifths of the lime; the action of both being the same, molecule for molecule, provided the stone is not burned to the point of insipient vitrification. Like hydraulic lime, the hydraulic property of natural cement depends upon the chemical combination of lime with the silica, alumina and iron. It differs from hydraulic lime, however, in that there is not sufficient free lime to cause the burned material to slake upon the addition of water; hence, it must be ground. Natural cement possesses greater hydraulic properties and shows much greater strength after setting than the hydraulic lime, but it is not so strong as Portland cement, which has a more definite chemical composition, as will be seen later. Natural cements vary from brownish yellow to brown. The initial set takes place in about 20 minutes after being mixed with water and the final set 3 to 5 hours later.

Analyses of Natural Cement Rocks from Northwest Georgia[1]

	1	2	3
Silica (SiO_2)	5.28	6.52	22.93
Alumina (Al_2O_3) } Ferric oxide (Fe_2O_3) }	2.62	.96	4.16
Lime (CaO)	30.60	47.98	33.80
Magnesia (MgO)	17.25	1.25	.45
Sulphur trioxide (SO_3)	.02	.....	.03
Phosphorus pentoxide (P_2O_5)	.04	trace	.02
Clay bases (Al_2O_3, K_2O, Na_2O)	3.83	2.58	10.43
Carbon dioxide (CO_2) } Water (H_2O) }	40.36	40.71	28.18
Total	100.00	100.00	100.00

1. Natural cement rock from Cement, Bartow County, Georgia.
2 and 3. Natural cement rock from Rossville, Walker County, Georgia.

Natural cements are burned in kilns quite similar to the ordinary lime kiln, but larger. The kilns are operated continuously with the fuel and limestone fed in at the top, together or in alternating layers. As mentioned above the temperature used for burning is only slightly above the temperature of de-carbonization. The burned stone is drawn from the bottom, cooled and ground so as to pass 40 or 50 mesh. Descriptions of kilns and grinding machines are given in other parts of this report.

Portland cement is the resulting material from an artificial or natural mixture of calcium carbonate, silica, alumina, and iron oxide, in definite proportions, burned to the point of incipient vitrification and the clinker ground to a fine powder. Calcium carbonate and silica are the principal ingredients of the raw material, which after being burned forms a tri-calcium silicate. There must be present, however, some other material to act as a flux which lowers the temperature of vitrification sufficiently to put it on a commercial basis.

[1] Maynard, T. Poole, Limestone and Cement Materials of North Georgia: Bull. Ga. Geol. Survey, No. 27, 1912, p. 35.

Alumina serves this purpose. Ferric oxide is always present and may be considered to act similarly to alumina, molecule for molecule. The ratio of lime to silica plus alumina plus iron oxide in the final cement should be about 2 to 1, but may vary slightly. The ratio of silica to alumina plus iron oxide should be between 2 to 1 and 3.5 to 1. The magnesia content of the final cement should be less than 5 per cent. Various combinations are used to obtain these proportions. The sources of calcium are marl, argillaceous limestone, chalk, hard, high-calcium limestone and marble, while silica and alumina are derived from clay, shale, and slate. Sand grains and pebbles must be absent in these materials.

In the following table are given analyses of the limestone, clay, mixture and the finished cement:

Analyses of Cement Materials and Finished Product (Eckel)[1]

	Raw materials		Finished products	
	Limestone	Clay	Mixture	Cement
Silica (SiO_2)	1.16	57.06	22.20	22.42
Alumina (Al_2O_3) ..	.75	10.01	5.02	5.68
Ferric oxide (Fe_2O_3)	.75	5.37	2.85	3.22
Lime (CaO)	49.44	8.32	65.79	62.24
Magnesia (MgO) .	2.04	5.22	4.06	3.22
Loss (H_2O, CO_2, etc.)	46.04	14.00	undet'd.	undet'd.
Total	100.18	99.98	99.92	96.78

In preparing the raw materials to be burned, analyses are made of the limestone and clay, or whatever the materials may be, and the properties of each to be added to make the mixture calculated. They are then ground and mixed thoroughly. The mixture is then ready to be burned. It is fed into the upper end of a rotating kiln which slopes gently to the lower or firing end. The kilns are from 5 to 7 feet in diameter and 60 to 200 feet long. The outside is of sheet steel and the inner lining fire brick. Pulverized coal, gas or oil, which is

[1] Eckel, E. C., Cements, Limes and Plasters, 1905, p. 397.

blown in through a small pipe at the lower end of the kiln, may be used for fuel. As the kiln rotates the mixture works its way to the lower end of the kiln where it is discharged as a clinker which has been burned to the point of incipient vitrification. The clinker is seasoned for a number of hours and then ground. In this state the cement will "set" too rapidly, hence a small quantity of gypsum is added to retard this.

The prospects for the manufacture of Portland cement in South Georgia seem to be rather remote; the raw materials occur in quantity, but the distance is too great from the source of fuel supply.

The uses of hydraulic cement are so well known that it seems useless to dwell upon them here.

The manufacture of hydraulic cements has been touched on rather lightly in this report, but is gone into more thoroughly in Bulletin 27 issued by the Geological Survey of Georgia.

SAND-LIME BRICK

Sand-lime brick, although little used in the South, are reaching a very extensive use in some of the Northern states and Canada. In Germany the industry has reached a higher state of development than in any other country, there being some 300 plants within its borders. The brick is essentially a mixture of silica sand and lime molded and pressed into brick form and then subjected to steam under a pressure of 100 to 150 pounds per square inch for from 4 to 10 hours. The steam causes a chemical combination between the silica and the calcium of the lime, forming calcium silicates. The brick has been gradually evolved from the old "mortar brick" of some fifty or more years ago, which was a mixture in about equal proportions of hydrated lime and sand molded into brick form and allowed to harden in the atmosphere. The hardening in this process was by the absorption of carbon dioxide by the lime to form calcium carbonate. This is the change that is undergone in ordinary lime mortars and plasters of the present day.

The following table[1] shows the quantity and value of sand-lime brick produced in the United States in 1913 and 1914.

Quantity and Value of Production of Sand-Lime Brick in the United States, 1913 and 1914

Year	No. active firms reporting	Quantity (thousands)	Value
1913	68	189,659	$1,238,325
1914	62	172,629	1,058,512

In the year 1903, practically the first year of the industry in the United States, the value of sand-lime brick produced was $155,040.

MATERIALS

As the name indicates, sand-lime brick are made of sand and lime. Since the strength and hardness of the brick depends upon the chemical combination of silica and calcium the sand must necessarily be silica. Any impurities act as adulterants and may affect the strength of the product provided there is enough present. Clay derived from the decomposition of feldspar is the principal impurity met with. When the clay present is less than 10 per cent of the sand it is probably not injurious while as much as 2.5 per cent might be desirable, as it fills the voids and makes the brick less porous.[2] A medium grained sand containing enough fines to fill the interstices between the larger grains is considered best, that is, a sand all of which will pass 40 mesh and 10 per cent through 150 mesh. Sharp sand has better binding qualities, molds more easily, and better retains its sharp edges and corners.

Tests made by different investigators tend to show that a high-calcium lime is better for making sand-lime brick than magnesian lime. High-calcium lime is more readily slaked, and hence assures all of the lime in the molded brick to be in the form of the hydroxide

[1] Middleton, Jefferson, Mineral Resources of the U. S. for 1914, Part II, Sand-Lime Brick, p. 2.

[2] Peppel, S V., Ohio Geological Survey, Bull. 5, 4th Ser., 1905, p. 33.

before going to the hardening cylinder, otherwise the brick is liable to be ruptured by the expansion of the slaking magnesian oxide. Also, the calcium hydroxide is a much stronger base than magnesium hydroxide and attacks and unites with the silica more readily, thus making the operation more rapid.

MANUFACTURE OF SAND-LIME BRICK

Practically the only variation in the manufacture of sand-lime brick is the methods of mixing the sand and the slaked lime previous to going to the press. There are two main methods each of which has several variations: (1) mixing hydrated lime, sand and water, and (2) mixing caustic lime and sand and then adding sufficient water to hydrate the lime and form a stiff putty. In the first method the hydrated lime and sand may be mixed in the dry state and then water added or the lime may be slaked with enough water to leave a stiff putty after the sand is incorporated. In the second method a part or all of the sand may be mixed with ground or lump lime and then slaked and well mixed in a suitable mill. The putty may be pressed into brick at once or allowed to season for about 24 hours. The "seasoning" is for the purpose of thoroughly slaking the lime, otherwise the brick is liable to be ruptured by the expansion of the slaking lime.

When the damp mixture of hydrated lime and sand is obtained it is molded and pressed by a machine similar to those used in the manufacture of dry-pressed brick. According to Peppel[1] the best results are obtained by using a pressure of 15,000 pounds per square inch. After the brick have been molded they are stacked on cars and rolled into a long steel cylinder. These cylinders are usually 7 feet in diameter and 40 to 60 feet long. The brick are here subjected to steam under a pressure of 125 to 150 pounds for from 4 to 8 hours, and upon cooling are ready for use.

[1] Peppel, S. V., The Manufacture of Artificial Sandstone or Sand-Lime Brick: Bull. Ohio Geol. Survey, No. 5, 4th Ser., 1905, p. 44.

The following is compiled from five tests made by Peppel[1] on sand-lime brick molded under 15,000 pounds pressure and hardened in a pressure of 150 pounds of steam:

Strength of Sand-Lime Brick (Peppel)

Hours in steam	Crushing strength		
	Maximum	Minimum	Average
4	7896	4441	5447
8	7404	4491	5654

Absorption tests show from 6.5 to 12 per cent porosity, average about 8.3 per cent.

The summary of the averages of a series of tests made on common clay brick by Dr. H. Ries[2] is as follows:

	Maximum	Minimum	Average
Crushing strength	5796	1192	3207

The porosity varies from 7 to 17 per cent, averaging about 12 per cent.

A comparison of the results in the two tables shows the sand-lime brick to be superior to common brick. Pressed or hard-burned clay brick show a higher crushing strength and lower absorption percentage than sand-lime brick.

The cost of manufacture of sand-lime brick depends mainly upon the cost of labor, sand, lime, and fuel. The cost per thousand, according to different authorities, varies from $3.50 to $5.00, averaging probably $4.50.

INDUSTRIAL CHEMISTRY

BLEACHING AGENTS

Limestone is used in the manufacture of the bleaching powder known as chloride of lime (calcium hypochlorite). Only very pure high-calcium limestones are used; those which leave little or no resi-

[1] Op. cit., p. 46.
[2] Ries, H., Building Stones and Clay Products, 1912, p. 302.

due when treated with acid. The stone is first burned in ordinary lime kilns and then hydrated and allowed to stand for several days. The dry calcium hydroxide powder is then spread over the floor of lead or iron chambers for a thickness of 3 to 4 feet. Chlorine gas is passed in at the top of the chamber which quickly permeates the hydrated lime and forms calcium hypochlorite. This material is used as a disinfectant, an oxidizing agent and more especially for bleaching cotton fabric.

The greater portion of chloride of lime is produced by electrolytic alkali works in order to utilize the large quantities of chlorine gas generated. The United States imports a large quantity annually from Europe.

SODA

The LeBlanc process for the manufacture of soda or sodium carbonate is by heating to redness in a small rotary kiln a mixture of sodium sulphate, obtained by treating salt ($NaCl$) with sulphuric acid (H_2SO_4), coal or coke and limestone. By this treatment a mixture of sodium carbonate, calcium sulphide, and impurities contained in the coal and limestone is obtained. This mixture is placed in suitable vats and the soda leached out by water, the calcium sulphide is practically insoluble. The solution is then evaporated and the soda recovered.

Soda is manufactured by the Solvay process as follows: Carbon dioxide, generated by calcining limestone, is passed into a saturated solution of common salt ($NaCl$) and ammonia (NH_4OH). Sodium bicarbonate ($NaHCO_3$) precipitates out and the liquid is filtered off. Upon heating the sodium bicarbonate in a suitable kiln sodium carbonate remains. The filtered solution from the sodium bicarbonate is treated with lime in order to recover the ammonia, a solution of calcium chloride results which is recovered by evaporating the water of the solution.

Soda is used in large quantities in the manufacture of soap, glass, paper and many sodium salts, in laundries, preparation of textile fibers and dyeing. Calcium chloride is used largely by artificial ice factories for the brine solution.

AMMONIA AND ILLUMINATING GAS

Most of the ammonia (NH_3) used today is prepared as a by-product in the manufacture of metallurgical coke or illuminating gas. The gases distilled off from coal are passed through water which absorbs the ammonia. When the "mother liquor" thus obtained is heated in suitable vats with lime, gaseous ammonia is distilled off and is passed through sulphuric acid. Ammonium sulphate crystallizes out. If aqueous ammonia is desired water is used instead of sulphuric acid. This process serves two purposes; it cleans the illuminating gas of some of its objectionable constituents, as well as recovers the valuable by-product.

Ammonia is used in laundries, dyeworks, textile print works, color factories and the manufacture of ice.

Ammonium sulphate is used to a great extent in Europe as a nitrogen-supplying fertilizer. A comparatively small quantity is produced in the United States annually.

CALCIUM CARBIDE

Calcium carbide, so widely used for generating acetylene gas for illuminating purposes and high temperature flames, is manufactured by fusing in an electric furnace a mixture of high-calcium lime and charcoal.

CALCIUM CYANAMIDE AND NITRATE

Calcium cyanamide and calcium nitrate are manufactured by treating milk of lime with nitrogen dioxide which is made by an electric spark in air in a suitable receptacle. These materials have been placed on the market within recent years as fertilizers.

LIME LIGHT

When a flame of intense heat plays upon a piece of calcium oxide or lime a very brilliant light is obtained. These lights are used mainly in lighthouses.

RECOVERY OF MERCURY

Mercury is recovered from its ore cinnabar (HgS) by some producers by heating a mixture of cinnabar and lime. In this way comparatively pure mercury is distilled off, leaving calcium sulphide and calcium sulphate.

WATER SOFTENING

The "hardness" of some waters is due to the presence of calcium bicarbonate. If the carbon dioxide can be driven off in some way the larger proportion of the calcium carbonate will precipitate. This may be accomplished by heating, which method, however, is not practicable for a city water supply. If caustic or hydrated lime is added to the water it will combine with the carbon dioxide to form calcium carbonate which will precipitate, together with that already held in solution.

GLASS MANUFACTURE

There are four principal varieties of glass, namely, plate, window, green bottle, and flint. The first three mentioned are essentially silicates of sodium and calcium and are made by fusing in a suitable refractory pot a mixture of silica (sand), sodium sulphate or carbonate, and calcium carbonate (limestone). The limestone is from 15 to 26 per cent of the mixture, varying with the variety of glass. The mixture from which lime-flint glass is made contains about 8 per cent calcium hydroxide (slaked lime), while lead-flint glass contains no calcium. The limestone used in this industry must be practically free from iron, clay, magnesium, etc., except in the manufacture of green bottle glass.

CERAMICS

Limestone, both high-calcium and magnesian, are used to some extent in the manufacture of certain grades of porcelain and pottery. For wares burned at moderate temperatures certain authorities state that calcium oxide tends to bring together the points of vitrification and fusion of the clay, while magnesium oxide tends to separate them and at the same time lower the temperature of vitrification and decrease the shrinkage and warping due to burning. If vitrification of the clay begins before the limestone is thoroughly de-carbonated pin or blow holes may be developed. In this case it is necessary to use the oxides or hydrates.

Limestone is also used in certain processes of glazing pottery.

SUGAR MANUFACTURE

High-calcium limestones are used in both the beet and cane sugar industries. Lime and carbon dioxide are both desired, hence the limestone is burned in kilns arranged so that the gas can be recovered.

The juice pressed from cane and beets contains organic impurities which would color the final sugar and hinder its crystallization if not removed. In order to accomplish this removal the juice is boiled with an excess of lime. The lime neutralizes the organic acids and unites with the other impurities with the formation of insoluble salts. These are allowed to settle and the solution of sugar and excess lime drawn off. The lime has entered into chemical combination with the sugar. Since lime has a greater affinity for carbon dioxide than for the sugar compound, this gas is passed into the solution and calcium carbonate precipitates, leaving a clear pure solution of sugar. If silica is present in the lime it will gelatinize and clog the filters. If magnesia is present it will remain partly in solution after the treatment with carbon dioxide and form scales on the evaporating pans.

DISTILLATION OF WOOD

Wood alcohol, acetic acid, and acetone are derived from the distillation of wood. The crude acid is treated with an excess of caustic or hydrated lime and distilled. Alcohol passes off leaving acetic acid in solution with the lime. Upon the addition of sulphuric acid, calcium sulphate is formed, and the acetic acid released. It may then be distilled off. If acetone is desired the solution of acetic acid and lime, known as "gray acetate of lime," is distilled dry. In order to purify the wood alcohol it is re-distilled in the presence of lime.

Calcium oxide and carbon dioxide are the only useful[1] constituents of the limestone, but the other impurities are not harmful, being adulterants.

PAPER MANUFACTURE

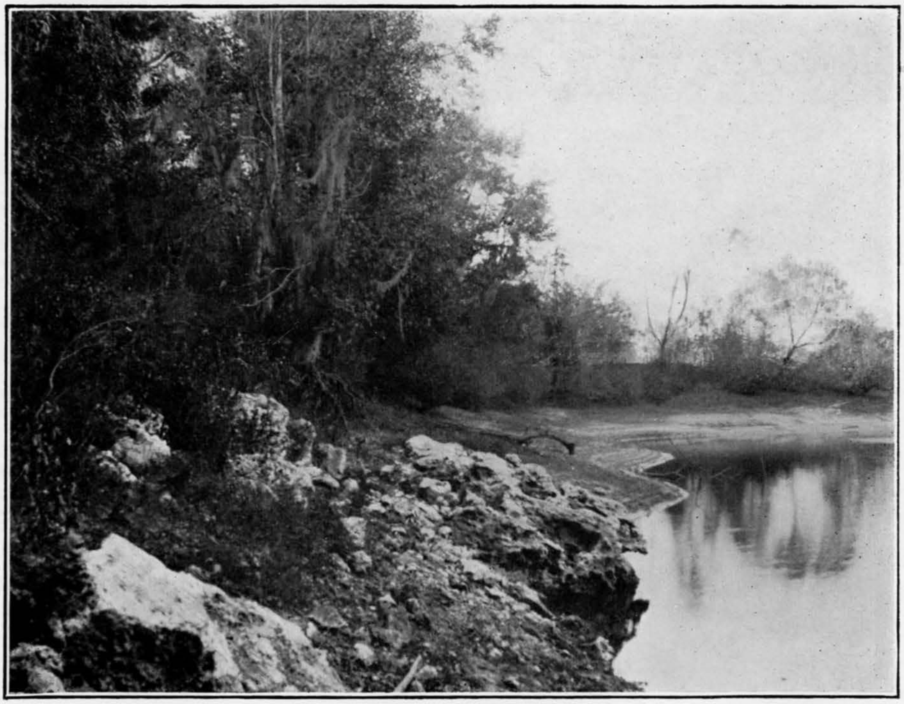
Rags, etc.—In the manufacture of paper from rags, etc., caustic lime is used to destroy the grease and fatty materials absorbed in the cloth.

Wood Pulp.—Lime is used in two processes for the manufacture of paper from wood pulp, namely, the soda process and the sulphite process. In the former method the wood is cooked by caustic soda, the latter taking up carbon dioxide and forming sodium carbonate. In order to change the carbonate back to caustic soda, so that it may be re-used it is treated with lime which unites with the carbon dioxide forming calcium carbonate.

Bisulphite liquor, a solution of calcium and magnesium bisulphite and sulphur dioxide, is used in the "sulphite process" for cooking the wood pulp. The bisulphites are formed by treating limestone or lime in water with sulphur dioxide. High-magnesian limes are said to be more desirable because of the greater solubility of the magnesium bisulphite. It also gives a whiter color and causes the pulp to felt more easily.

[1] Dumesun, P., and Moyer, J., Wood Products, Distillates and Extracts, p. 8.

A. EXPOSURE OF FLINT AND LIMESTONE OF THE JACKSON GROUP JUST ABOVE DEWITT FERRY, FLINT RIVER, MITCHELL COUNTY.



B. SINK IN CHATTAHOOCHEE LIMESTONE, SHOWING THE LIMESTONE AT EDGE OF POND, ORIGINAL POND, 3 MILES WEST OF METCALF, THOMAS COUNTY.

GLYCERINE, LUBRICANTS, AND SOAP

In the manufacture of glycerine, lubricants and soaps and allied products, high-calcium lime is used to break up the fatty substances from which the products are derived. Glycerine is liberated upon the distillation of the fats with lime in water. The remaining material is used to manufacture lubricating greases for heavy machinery and for soaps.

TANNING

In the leather industry the hides are soaked in lime water to loosen the hair so that it can be easily removed by scraping. Both high-calcium and magnesian limes are used.

METALLURGY

BLAST FURNACE FLUX

One of the most important uses of limestone is as a flux in iron blast furnaces. High-calcium limestones are more generally used, but in certain sections, namely, Birmingham, Ala., and vicinity, dolomite and dolomitic limestones are used almost entirely.

The value of the stone depends upon its physical and chemical character, that is, it must be hard and compact enough not to dust easily, and it must contain as little silica, alumina, sulphur, and phosphorus as possible. Silica and alumina act as adulterants and must be fluxed off as well as the same impurities in the iron ore. Sulphur and phosphorus are detrimental to the iron itself if present above a certain low percentage, however, few limestones contain sufficient percentages of these elements to make them unfit for fluxing purposes.

The relative values of calcium and magnesium as bases for fluxing off the acidic content of the ore seems not to have been definitely determined by the manufacturers of iron or by research students, but both high-calcium and dolomitic limestones are used by successful iron producers.

The stone is crushed to sizes from 2 to 4 inches in diameter and charged into the top of the furnace alternately with ore and coke. The coke serves as the heating agent as well as producing the reducing action upon the oxides of iron in the ore. The calcium and magnesium of the limestone unite with the silica, clay bases and other impurities to form silicates which compose the slag.

LINING OF BASIC OPEN-HEARTH FURNACES

An important use of dolomite and dolomitic limestone, although a comparatively small tonnage is so employed, is the lining of basic open-hearth furnaces for the manufacture of steel. Magnesite is the ideal material for this purpose, but owing to its high cost it is being generally replaced by dolomite. The furnace has an outer wall several feet thick of common brick within which is a permanent lining of 2 to 3 feet of magnesite brick. Upon this lining 1 to 2 feet of crushed dolomite, together with a suitable binder, is tamped. The object of the crushed stone is to take care of the wear due to the mechanical and chemical action of the molten metal and slag, it being much cheaper to replace than the refractory brick. To answer this purpose the stone must be as low as possible in silica and the clay bases and at the same time approach very nearly a theoretic dolomite. It must also be hard so as to resist mechanical wear and must neither crack nor slake when the furnace is cooled.

It is rather improbable that there are any limestones in South Georgia which answer the above requirements.

BASIC OPEN-HEARTH FURNACE FLUX

Limestone is used as flux in the manufacture of steel by the basic open-hearth process. The fluxing action is similar to that in the blast furnace, that is, it carries off the silica, alumina, sulphur, manganese and phosphorus. Therefore, a stone as low as possible in these impurities is desired. Magnesium is objectionable in that it has less affinity for sulphur and requires a higher heat to complete the fluxing action. The stone in general use usually contains less than 5 per cent magnesia, less than 1½ per cent alumina, and less than 1 per cent silica. Few limestones contain sufficient amount of sulphur and phosphorus to render them unsuitable for flux. The stone must be hard and compact enough to prevent its being ground into dust by hauling.

In addition to iron smelting limestone is also used in copper and lead smelting.

QUARRYING LIMESTONES

Quarrying is the first and one of the most important steps in the production of limestone and its products and yet very little has been published on and apparently little study given the operation. Practically every deposit of limestone is governed by certain local conditions and is a problem within itself, hence few general statements can be made which cover the work as a whole. Only one general method need be dwelled upon to any extent, namely, quarrying. It is sometimes necessary to resort to underground mining, but this is so expensive compared to the value of the limestone product that it need be considered only lightly.

TYPE OF WORKINGS AND LOCATION

There are two general types of quarries, the hillside type and the pit or open cut quarry. It is seldom that the operator has the opportunity to choose which of the two methods to work a given deposit by; usually the limestone body is so situated that only one type quarry can be opened. If the operator can make a choice, however, he should work the deposit as a hillside quarry since they are practically always cheaper to operate than pits. In the latter there is the extra expense of lifting the stone from the floor of the quarry to the top of the face and the removal of water from the working. The other costs are practically the same as for hillside quarries.

The site for the workings should be chosen with regard to (1) overburden, (2) strike and dip of the strata, (3) drainage, (4) haulage grade to mill or kilns, (5) mill or kiln site, and (6) transportation. These factors are not arranged according to their importance, which is governed by the local conditions. The demand and composition of the stone are not taken into consideration, as it is supposed these are known.

The overburden or superincumbent material on the limestone governs to a great extent the workability of a given deposit. It is obvious that a great thickness of valueless material cannot be moved for a comparatively thin bed of limestone on an economic basis. Hence, it is necessary to locate the quarry where a minimum amount of overburden will have to be moved. The maximum thickness that can be handled is governed by the workable thickness of the underlying limestone.

When limestone outcrops along the base or side of a hill it is evident that the farther the workings are extended into the hill the heavier the overburden. Under these conditions it is usually practicable to move a greater maximum thickness of overburden than from a deposit under level ground, since on the hillside deposit the mean thickness is less than the maximum. Where the conditions are suitable it is more economical to "edge" the hill than to work straight in for any distance.

Strike and dip need not be considered in the Coastal Plain deposits, since all of the beds are level, or practically so.

In the hillside quarry the floor should be always kept above the drainage level if possible to avoid the necessity of removing such water as might accumulate from seepage, rain, or flood stages of a near-by stream. In a pit quarry it is, of course, impossible that the quarry be so situated that it will have natural drainage except where tunnels can be employed.

An important item in the cost of quarrying is the hauling of the broken stone from the quarry to the mill. It follows, therefore, that it is expedient to put the mill as close to the quarry as possible without it being in danger from blasting. If the conditions make it possible the haulage cost can be greatly reduced by working the deposit at such an elevation that the tram cars will run by gravity to the mill, preferably to the feed bin of the first crusher or the top of the lime kiln, as the case may be.

The site for the plant is governed by the location of the quarry and possible location for the spur track from the main line of the railroad. Railroad construction is rather expensive, hence the necessity of locating the workings as near the main line as possible. This expense is usually partially borne by the railroads under certain conditions.

STRIPPING

Stripping or removing the overburden from a deposit of limestone may be done by one or more of a number of different methods, namely, pick, shovel and wheelbarrow, plow and scrapes, hydraulic giant, or steam shovel. There are other implements and machines in use, but those named are the most generally used, especially where the development work is rather limited. The material to be moved governs to a great extent the methods to be used. The deposits that this report deals with, however, are covered usually with sand, sandy clay, or clay with sometimes flint boulders, so that any one of the above methods can be applied.

The most expensive method of excavating and removing overburden is by pick, shovel and wheelbarrow or wagon. These tools can only be applied economically where the overburden is very thin or the conditions such that other implements cannot be employed.

The plow and scraper are probably the most efficient implements that can be employed on account of their adaptability and comparatively cheap operative cost. While costing more per yard to move the dirt than by other mechanical means the outlay of capital is comparatively small. The plow is necessary to loosen the earth before the scraper can be filled. Of the two types of scrapers the drag scrape is more suitable for close work and short hauls and the wheel scrape for open work and long hauls. The latter should be used whenever possible, since it has a larger capacity than the former, and being on wheels is much easier on the team.

A hydraulic giant is a large flexible water nozzle through which water is forced at high pressure and played upon the bank of material to be moved. The dirt is thus washed off of the underlying deposit. It is, of course, necessary to have an ample supply of water close at hand if the hydraulic giant is to be used. This is a comparatively cheap method, but the outlay necessary to install adequate pumping machinery is rather large.

The cheapest means of excavating the overburden, provided it is heavy, is by the steam shovel. A steam shovel can operate most efficiently in loose material sufficiently thick to allow the shovel to be in the dirt from the lower to practically the upper limit of its stroke. But where the overburden is of such a thickness, say 15 feet, it usually will not pay to move it for the underlying limestone.

DRILLING AND BLASTING

After the overburden has been removed the next operation is breaking the stone from the bed into sizes that can be conveniently handled. This is most economically done by drilling and blasting with powder or dynamite.

Holes in which the powder or dynamite is placed are drilled in the rock by hand or machine. Hand drills are of two types, one operated by two men, one holding the bar of drill steel while the other strikes the head with a heavy hammer, and the other type is a longer bar that is raised and dropped by one man. The drill must be rotated to prevent jamming. Water is nearly always poured in the hole to keep the chips and dust of stone loose so that they will not tighten the steel. Hand drilling can be most economically employed where the rock is soft or the workings small. Machine drills suitable for the type of quarry operations to be met with in South Georgia are of two general types, the piston and the hammer drills. The piston drill (see Fig. 6) is the larger machine and operates from a tripod or other movable stand. These drills are operated by compressed air, frequently, together with a little steam. The movable parts of the

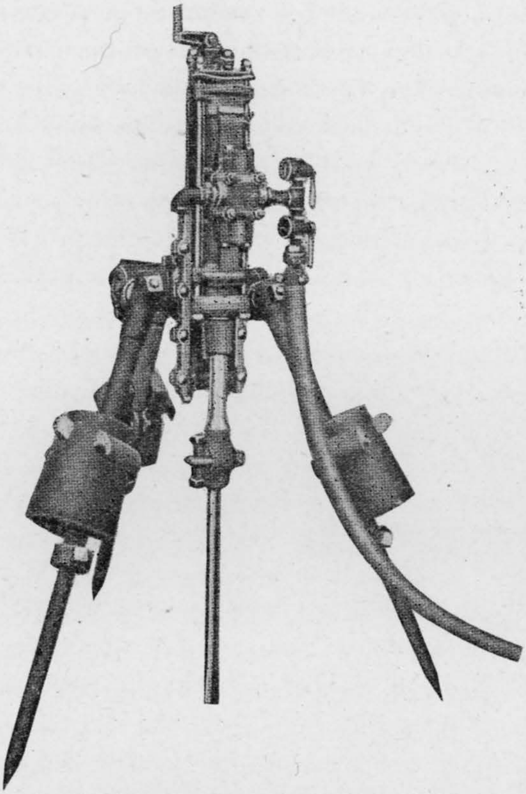


Fig. 6.—Ingersol-Rand Piston Drill on Tripod

machine are the valve mechanism and the piston. The boss which holds the drill bit is made rigidly to the piston and hence the stroke of the bit is the same as that of the piston, working somewhat along the same principal of hand steel which is raised and dropped. These machines drill vertical or sloping holes 1 to 3 inches in diameter and 1 to 20 feet in depth, according to the size machine used. The machines work on about 75 pounds air pressure, making 300 to 500 strokes per minute. The drill steel used is solid hexagonal bars from three-fourths to 1¼ inches in diameter. The steel should be of the best quality and properly tempered in order to get the maximum efficiency out of the machines. The bits rotate automatically. Two men, the "machine man" and the "chucker" or helper, are necessary to operate the machine under ordinary conditions. The latter assists in placing the machine and feeds water into the drill hole. The machine is so built that as the hole is driven the cylinder is moved down a slide bar to keep the drill bit hard against the bottom on the out stroke. This is operated by hand by the machine man. Mounted and ready to drill the machine weighs from 400 to 1200 pounds, according to size. The piston drills are used for hard rock and deep holes.

The machine best suited for light work is the air hammer drill (See Fig. 7). These are of light weight, varying from 40 to 75 pounds, and require no support, being held by hand. They can, therefore, be carried from place to place with the greatest ease and set to work immediately. The moving parts of the heavier hammer drills are the piston and valve. The steel slips up into the lower end of the piston and is pounded either directly or through an anvil block by the piston. Three-fourths inch hollow steel is usually used. The hollow is for the purpose of blowing air into the hole to remove the chips and dust. The steel is self-rotary in most hammer drills. Under the best conditions 100 to 150 feet of holes per day can be drilled, 75 to 100 pounds air pressure being most efficient.

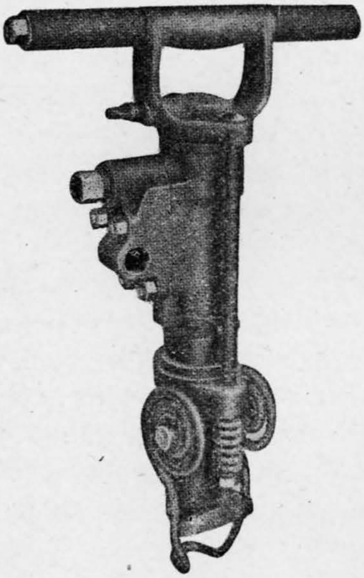


Fig. 7.—Ingersol-Rand Jackhammer

These machines are especially adapted to quarries where the benches are not over 10 feet and all or most of the drilling is vertical or nearly so. They are also useful for drilling shallow holes in boulders too big to be handled conveniently without breaking.

The powder or dynamite to be used in quarrying depends upon the hardness and toughness of the stone and the products to be made. A hard stone is more easily worked by dynamite, while a very soft one can be more satisfactorily broken with black powder. The percentage of dynamite and the grade of powder can best be determined by experience. Where crushed stone or agricultural limestone is the product the size of quarried rock may be practically any size that can be efficiently handled by the crushing machinery. When lime is the final product it is desirable to have as much of the stone as possible above a minimum size to prevent choking the furnace and below a maximum to assure thorough calcination.

BLOCKING

"Blocking" is the process of breaking the large pieces of stone to sizes which can be conveniently handled by the quarrymen or the crushers. It is accomplished either by blasting or breaking with heavy sledge-hammers. The blasting may be done either by drilling and firing a shallow hole with dynamite, "pop" shooting, or by placing the explosive flat on the rock and covering with clay and then firing. The latter is known by quarrymen and miners as a "mud" shot.

LOADING AND HAULAGE

The containers for conveying the broken stone from the quarry to the mill are in the large majority of quarries loaded by hand, where the operation is extensive, however, steam shovels are frequently employed. The haulage equipment varies widely in different quarries, being governed largely by local conditions. The following are the most common methods; wheelbarrow, cart, tram, and aerial tramway.

The wheelbarrow is used only when the haul is very short and the production small. It will find its greatest use in South Georgia in conveying stone from the quarry to small machines for grinding agricultural limestone for plantation or local use, where the plant can be erected very close to the deposit.

Carts drawn by mules or horses are used in a great many quarries where the operation is on a comparatively small scale and the haulage grade slight. A two-wheeled dump cart has the advantage over a four-wheeled wagon because it can be turned around in a small space and can be easily backed up to the crusher bin and the stone dumped without a second handling.

Tram cars with capacities of from one to five tons are most generally used in quarry operation. Temporary tracks that lead into the main line to the plant are laid along the quarry floor as close to the face as practicable. This allows a maximum number of cars to be loaded simultaneously. The method of conveying the cars from the quarry to the plant is governed by the distance and grade. Where the track is down grade to the plant the cars may run by gravity. This is very desirable since it eliminates a considerable part of the haulage cost. The empty cars may be pushed back by hand or drawn by mules or other power, according to the grade and distance. Where the plant is some distance from the quarry and the track grade such that the cars require pushing or pulling, motor power is most generally used, the cars being gathered at the loading point or on the main line where they have been pushed by the loaders.

Where the elevation of the crusher bin is considerably above that of the quarry floor it is usually necessary to draw the cars up by hoist and cable. The cars are assembled at the main hoist track and there attached to the cable, in groups or singly. Where the operation is on a large scale and the grade sufficiently steep two tracks can be used on the incline, loaded cars going up while the empties are coming down. This, of course, lessens the power necessary, as the hoist has the weight of the actual stone only to hoist and the friction to overcome.

Aerial tramways are occasionally used in transporting the stone to the mill. This method of transportation can be most satisfactorily applied to pit quarry operations or to hillside quarrying when the crusher bin is considerably above the quarry floor. An aerial tramway consists of a large cable stretched overhead from a tower at each end, on which a two tandem wheeled carriage runs. The carriage is pulled either to or from the engine, at the mill end of the way, by wire rope or cable. The bucket which contains the stone is raised to the carriage or lowered to the quarry floor by means of another cable, all controlled and manipulated by one operator. Several buckets may be used so that no time is lost by the tramway in waiting for the bucket to be filled. When the empty buckets are returned to the quarry loaded ones are picked up. The empties can be placed as desired, provided the distance is not too great, by being made to swing like a pendulum or pulled over by a rope attached, or they may be set down on flat tram cars and then placed as desired. The latter method is the most practical where the tramway comes in at right angles to the quarry face. When the cableway is parallel to the quarry the matter is simplified until the face is worked back considerably. The capacity of the cableway depends upon the size of the equipment and the transportation distance. Where very large capacity is desired a continuous cableway is used. A number of buckets are moved at the same time by this equipment. The empties are returned on one cable while the loads go in on another. When a bucket is stopped or slowed down to be emptied all on the cable are momentarily affected. At this juncture the empties are set off in the quarry and the loads picked up. This heavy duty cableway will probably find no use on the South Georgia limestone deposits.

All tram cars or cableway buckets should be so constructed as to give a minimum amount of trouble in dumping the stone. Various devices have been perfected which enable the carriers to dump their burdens automatically. The front end of the car is usually the door, swinging from the top. This has a holding catch which is knocked loose as it reaches the dumping point or tipple. The tipple may be so constructed that when the loaded car rolls onto a hinged section of the track the front end of the car will be lowered and the stone slide out. When the car is relieved of its weight the track assumes its normal position. Where the tipple track is rigid the car is so balanced on its truck that it will tip easily to the front. The back end may be raised by hand or mechanism.

STEAM SHOVEL EXCAVATING

Steam shovels are successfully used in some of the larger quarries in the country to handle the broken stone from the quarry floor into the cars. The operation must necessarily be on a comparatively large scale in order to utilize the full capacity of the shovel. The steam shovel is most efficient in excavating earth in railroad grading, building sites, canal work, removing overburden from workable mineral deposits, and excavating clays and shales for brick and cement work. The steam shovel might be used to advantage in the development of certain limestone deposits in the southern portion of the State. As stated under "stripping" the steam shovel will find little or no work in the removal of overburden unless it can be also employed in the quarry. The Jackson group contains several beds of very soft, argillaceous limestone and soft, friable, fossiliferous limestone, which could probably be worked to an advantage with a steam shovel.

THE MANUFACTURE OF LIME

One of the most important uses of limestone is the manufacture of lime. The mortar and plaster used in masonry, other than cement and concrete, and in other construction work depends upon lime for its cementing or binding qualities. It also finds a great variety of uses in industrial chemistry, agriculture, sand-lime brick manufacture and other industries.

Before the advent of railroads into South Georgia, the settlers found it necessary to burn their own lime. This was done by very crude methods. Usually the stone was burned on the site of the deposit in crude, simple kilns. The limestone was heaped in round or elongated piles, 6 to 8 feet high, with one or more tunnels left at the base or trenched out of the soil below for the fire (see plate VII-A).

The stone pile was subsequently plastered over with clay with an opening left at the top to allow the gases to escape.

In sections where a soft limestone was used for the manufacture of lime the stone was frequently quarried on a hillslope, leaving the faces of the quarry vertical and smooth, and, when a sufficient quantity of stone had been removed, the kiln was built by piling the loose stone back into the excavation, after which it was plastered with clay on the exposed side and ignited from below through suitable fire boxes. Wood was always used for fuel in these kilns and was probably frequently placed in alternating layers with the stone, as well as burned beneath. It was necessary to fire the kiln for several days in order to obtain a satisfactory product. Compared with a lime produced in a modern kiln the product of these crude kilns was probably poor, but it served very well the purposes to which it was applied, namely, mortar and plaster.

Near Sunhill, Washington County, there is a square, vertical kiln constructed of sandstone and chert braced with iron strips and rods. At Armena, Lee County, there is a kiln constructed along more modern lines, a sheet-iron cylindrical shell lined with fire brick. Neither of these kilns has been operated within recent years.

KILNS

There are two general types of kilns used almost altogether in the United States—the vertical shaft kiln and the rotary kiln. The latter type is not used to a great extent by lime manufacturers since the charge must be crushed to a small size, which makes it unsalable as lump lime. It is, however, well suited to the manufacture of hydrated lime. Rotary kilns will be referred to on page 279.

Under the head of vertical shaft kilns is included a number of different designs, varying but little in principle. They will be discussed here briefly in a general way. A shaft kiln is a short stack usually from 5 to 10 feet inside diameter or width, and 15 to 30 feet high. They may have square, rectangular, circular or elliptical cross

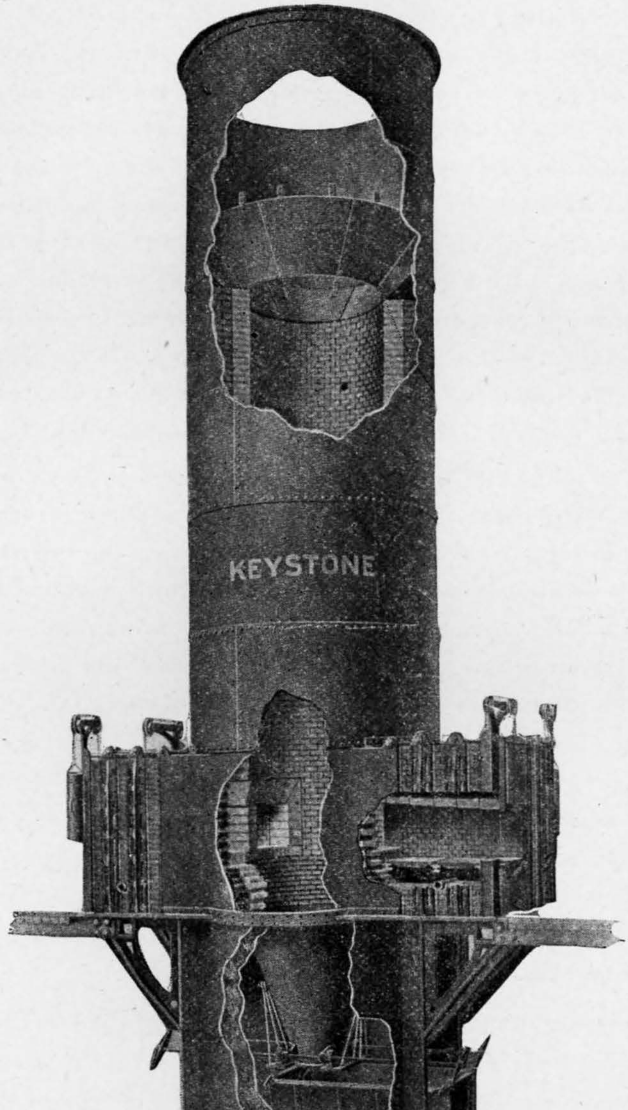


Fig. 8.—Vertical Lime Kiln

sections, both inside and out. The shape is usually governed by the material of which the outer wall is made. Stone kilns are, as a rule, either square or rectangular, while iron or steel and concrete are circular in cross section. The outer walls of a stone kiln may be built 15 to 18 inches thick with a lining of the same thickness of fire brick. Iron or steel rods should encircle the stone to add strength. If steel is used for the outside, a cylindrical shell is constructed of sheet steel, riveted together, and lined with 18 inches of fire brick. A 6- to 8-inch space should be left between the brick and steel to be packed with cinders, sand, or some other material of similar nature, to act as an insulator. The stone kiln loses less heat by radiation than the steel shell kiln, but the latter is stronger and requires less repairing. Concrete combines the good qualities of both.

The top of the kiln is left open to allow the gases to escape and for charging. The bottom is usually in the shape of an inverted, truncated cone supplied with a door through which the lime is drawn. Although in no way separated the interior of the kiln may be described as being divided into three zones. In the upper zone, or hopper, the stone receives a preliminary heating and as the stone is drawn from the bottom of the kiln, it works its way into the middle or burning zone where it is de-carbonated. It finally goes into the lower zone or cooler from whence it is drawn into wheelbarrows, cars, or onto the floor. The burning zone is considered to extend to the level of the grate of the fire-box. There is no distinct plane of division between the two upper zones. The location of this plane in the kiln is dependent upon the size of the kiln, the temperature of the fire, and the distribution of the heat.

Two to four openings, according to the size of the kiln, are left in opposite sides of the kiln walls, 4 or 5 feet above the base, for the fire-boxes. These boxes are similar to and about the size of those used under small steam boilers, and necessarily extend out from the wall of the stack. In certain types of kilns no fire-boxes are provided, the fuel is charged into the top of the kiln, alternately with the stone.

This method is objectionable on account of the mixing of the ash with the lime.

The construction of the kiln must be such, or mechanical means provided, that sufficient draft is obtained for two purposes, namely, in order that the fire may have a certain amount of oxygen to enable it to burn properly and that the carbon dioxide released from the limestone may be carried off as rapidly as generated. If this gas is not removed re-carbonization of the lime may take place and the object of the burning defeated. Nor should too strong a draft be used since an excess of air will cool the kiln to a certain extent.

The draft may be natural, induced, or forced. If the kiln is not high enough to produce sufficient draft, a stack may be erected on top with a door provided for charging. It is a well-known fact that the increase in the height of a smoke stack increases the draft. Induced draft is obtained by the employment of a suction fan in the stack at the top of the kiln. A combination of induced and forced draft is accomplished by forcing a part of the gases from the stack through the fire. With certain elaborations this is known as the Eldred process. Forced draft is usually secured by blowing steam through the fire. This has other advantages than producing draft, as will be seen later.

In all kilns where wood is used as fuel, natural draft has been found satisfactory.[1]

Kilns may be operated intermittently or continuously. By the former method the kiln is charged and then fired. When the de-carbonization is complete the kiln is allowed to cool and the charge then drawn. This is very wasteful of fuel, as the heat required to raise the kiln to the proper temperature takes no part in the de-carbonization, and, furthermore, much heat is lost in cooling. When a kiln is operated by the continuous process it is never allowed to cool except for repairs or to curtail the production. The stone is charged

[1] Emley, Warren E., The Manufacture and Use of Lime: Mineral Resources of the United States, 1913, Part II, p. 1570.

and drawn at short intervals, according to the capacity of the kiln and the quantity of the charge.

BURNING

Limestone when pure consists of calcium carbonate expressed by the chemical formula $CaCO_3$. When this material is heated to a certain temperature it breaks up into lime or calcium oxide (CaO) and carbon dioxide (CO_2), a gas, thus:

$$CaCO_3\text{(limestone)} + \text{heat} = CaO\text{(lime)} + CO_2\text{(carbon dioxide)}$$

If 100 pounds of limestone is used in this operation the result will be 56 pounds of lime, 44 pounds of carbon dioxide, the latter being driven off in the form of gas.

Under ordinary conditions of pressure limestone dissociates into lime and carbon dioxide at about 900° C. (1652° F). Practically all limestone contains impurities, usually in the form of silica or clay. At a temperature near 1200° C. (2192° F.), these impurities form chemical combinations with the calcium oxide.[1] When the stone has been heated to this temperature and above it is "over-burned." This is objectionable because it slakes very slowly and frequently has a yellowish color, which makes it unsuitable for certain purposes. Therefore, the temperature of the kiln should be kept between 900° C. and 1200° C. to obtain the best results. The combination of the calcium oxide with the impurities is said to be noticeable at an even lower temperature than the upper limit here given, hence the best lime is produced by keeping the temperature as low as possible. An exceptionally pure limestone may be heated considerably higher without over-burning. The length of time necessary to calcine the stone varies inversely with the temperature, hence a low temperature may be used for a long time or a high temperature for a shorter period.

The physical properties of the stone govern to some extent the temperature that should be used. It naturally takes a higher temperature and a longer time to calcine a large piece than a smaller

[1] Lime: Its Properties and Uses: Circular No. 30, Bureau of Standards.

one. The stone should not be so small, however, that it will prevent the easy passage of the gases through the kiln by the draft. Also a close, compact stone will conduct the heat more readily than one which is porous,[1] and is, therefore, de-carbonized more quickly.

In the preceding discussion only limestone has been considered. For most practical purposes the conditions are also applicable to dolomitic or magnesian limestone.

Heat for burning the limestone is derived from several sources. Wood and coal are principally used, but gas is also employed. Wood is considered to be the best fuel for the following reasons; the flame is longer than the coal flame and, therefore, carries the heat nearer the center of the kiln, assuring a more evenly burned lime, and the flame is not so hot as a coal or gas flame, so that the danger of overburning is less. Wood contains a rather large percentage of moisture which when changed to steam in the fire-box, greatly accelerates the de-carbonization and at the same time lowers the temperature of de-carbonization of the stone.[2] When coal and gas are used as sources of heat, steam is introduced beneath the fire-box. This cools the fire slightly as well as supplying moisture to assist the calcination of the stone. Coal is almost universally used by the large manufacturers owing to the scarcity of wood. Producer gas from coal is also used successfully. It eliminates the loss caused by unburned coal and coke falling through the grate bars.

CLASSIFICATION OF PROPERTIES

The National Lime Manufacturers' Association has adopted the following classification:

Classification of Limes

High-calcium lime contains 0 to 5 per cent magnesia
Magnesian lime contains 5 to 25 per cent magnesia

[1] Burchard, E. F., and Emley, W. E., The Source, Manufacture and Use of Lime: Mineral Resources of the United States, 1913, Part II, p. 1568.

[2] Peppel, S. V., Bull. Ohio Geol. Survey, No. 4, 4th Ser., 1906, p. 294.

Dolomitic lime contains 25 to 45 per cent magnesia
Super-dolomitic lime contains over 45 per cent magnesia.

Also the lime must contain not more than 5 per cent impurities, such as silica, oxides of iron and aluminum, etc., to meet usual specifications.

When water is added to lime it will slake; the water enters into chemical combination with the lime forming the hydroxide. Heat is generated by this union and the volume increases, causing the lumps to fall to a powder. If not too great an excess of water is added the heat generated will evaporate the moisture leaving a dry powder. If this material is exposed to the air for a length of time it will take up carbon dioxide and revert to the composition of the stone from which it was originally derived, that is, calcium carbonate (and magnesium carbonate). This is the re-action upon which the binding property of mortar is based.

The chemical composition of the lime governs to a certain extent the degree to which it possesses the above properties. High-calcium or "hot" limes slake rapidly and evolve much heat on the addition of water, while magnesian, or "cold" limes, slake more slowly and generate less heat, in proportion to the percentage of magnesium oxide present. The latter also expands less and will consequently give a smaller volume for equal weights.

If the lime contains over 5 per cent of such impurities as silica, iron and aluminum oxides it will slake slowly and is apt to have a yellowish color. These are known as "lean" limes. If the temperature of burning was sufficient to cause a chemical combination between the lime and the impurities it will have hydraulic properties, that is, it will set under water.

Under-burned lime contains calcium carbonate, which affects the rapidity and completeness of its slaking.

Since lime will absorb from the atmosphere carbon dioxide, it is important to keep it under conditions where as little air as possible can reach it. It is usually packed in wooden barrels in the lump, or in air tight bags in the ground state.

COST OF LIME MANUFACTURE

The principal items in the cost of lime manufacture are: the interest on the capital invested, the cost of quarrying, the cost of fuel for burning, and the cost of labor. Repair expenses should also be considered, but since this varies so widely it will not here be considered.

The interest on the cost of quarry and plant will vary according to the regularity with which it is operated. This is, of course, dependent mainly on the demand for the product.

The cost of quarrying depends on the variety of stone worked, whether it is easily drilled and broken down, or hard and tough. The position of the quarry face with regard to the structure and bedding of the deposit governs this to some extent. The amount of stripping and the efficiency of the management and the labor are likewise important. The plant should be located as near the quarry as practicable with the top of the kilns below the floor of the quarry. This will keep the haulage cost down to a minimum. Where pit quarrying is necessary inclines or elevators must be used to charge the kilns.

Allowing for waste, 2 tons of limestone will produce about 1 ton of lime. This means that to 1 ton of lime the cost of quarrying 2 tons of stone must be charged.

The cost of fuel is governed by the distance from the source of supply and the efficiency of the kilns and stokers as well as the first cost. When coal is used its consumption per ton of lime produced may vary from 300 to 500 pounds in modern kilns.[1]

The cost of labor at the plant and the overhead expenses may

[1] Eckel, Edwin C., Cements, Limes and Plasters, 1905, p. 110.

vary between wide limits. Eckel[1] has compiled the following cost data:

Total Cost of Lime Manufacture per Ton

Interest on cost of plant and quarry......	$0.05 to $0.20
Taxes, minor supplies, etc...............	.10 to .25
Cost of quarrying 2 tons of limestone.....	.50 to .90
Cost of fuel for burning.................	.30 to .75
Cost of labor, exclusive of quarrymen.....	.25 to .80
Total cost of burned lime per ton (2000 lbs.) in bulk............	$1.20 to $2.90

The minimum cost is for a modern plant run steadily under competent management.

HYDRATED LIME

The slaking of lime by unskilled labor is often unsatisfactory, due to burning or the incompleteness of the operation. In order to eliminate this objectionable feature, certain lime manufacturers have placed on the market, within recent years, a product known as "hydrated lime," that is, lime that has been slaked by the manufacturer. This material may be used for any purpose in the place of lime with the same results. The one objection is that the consumer must pay the freight on the water combined with the lime in hydrating, but the cost of slaking is eliminated. The addition of water is all that is necessary to prepare the hydrated lime for use.

In preparing the lump lime to be slaked it is first crushed or ground. The size to which the lime is broken varies with the manufacturer and the process of hydration used, but is usually less than one inch. The crushed material is then placed in a pan with agitators or in a horizontal revolving cylinder, containing slightly more than sufficient water to complete the hydration. The lime may all be added at once or gradually. The heat generated dries out the excess water, leaving a dry, finely divided powder.

If the lime was over-burned the material resulting from the combination of the calcium with the impurities will not slake, likewise

[1] Ibid.

if it is under-burned the calcium carbonate will remain in lumps. The slaked lime is consequently screened, usually through 50 mesh, to remove these impurities. It is then put up in 40-pound paper bags or 100-pound burlap bags and is ready for the market.

MACHINES FOR PREPARING LIMESTONES

The machines to be used in plants for the preparation of limestone for the market depend on the type of stone and the products desired. It is very evident that a machine suitable for working soft limestone may not be capable of working hard limestones; also, a plant containing machines for the production of the various sizes of crushed stone differs widely from a cement plant. However, the systems interlock to a great extent. The product from a crusher contains stone from very fine dust up to the maximum size of the opening of the crusher discharge. It is desirable to market all sizes to prevent waste. The different machines will be discussed briefly on the following pages.

ROCK BREAKERS

Rock breakers for coarse crushing are divided into three general classes: (1) jaw crushers, (2) gyratory breakers, and (3) roll crushers. These machines vary in capacity from 5 to 500 tons per hour and crush to minimum sizes of one-half to 5 inches. The capacity varies with the size of stone discharged. For example, the capacity of a breaker crushing to a size that will pass a 1½-inch ring is only slightly more than half as great as when crushing to 2½ inches. The larger the machine used the larger the size of the minimum sized product, hence it is frequently necessary to use two or even three sets of breakers in order to reduce the stone to the desired dimensions. Screens are used between the breakers of different sizes to eliminate the stone broken to the desired size in the first machine.

JAW CRUSHERS

Jaw crushers are the oldest of the heavy-duty, coarse-crushing machines, the first one having been built in 1858 after the design of Eli W. Blake, and has been since that time known as the Blake crusher or breaker. The principal parts of all jaw crushers are a stationary jaw plate, usually vertical, and a swing jaw plate which forms an angle with the stationary plate. The latter is given a reciprocating motion by a suitably arranged eccentric and pitman. Fig. 9 is a sectional view of a Blake breaker.

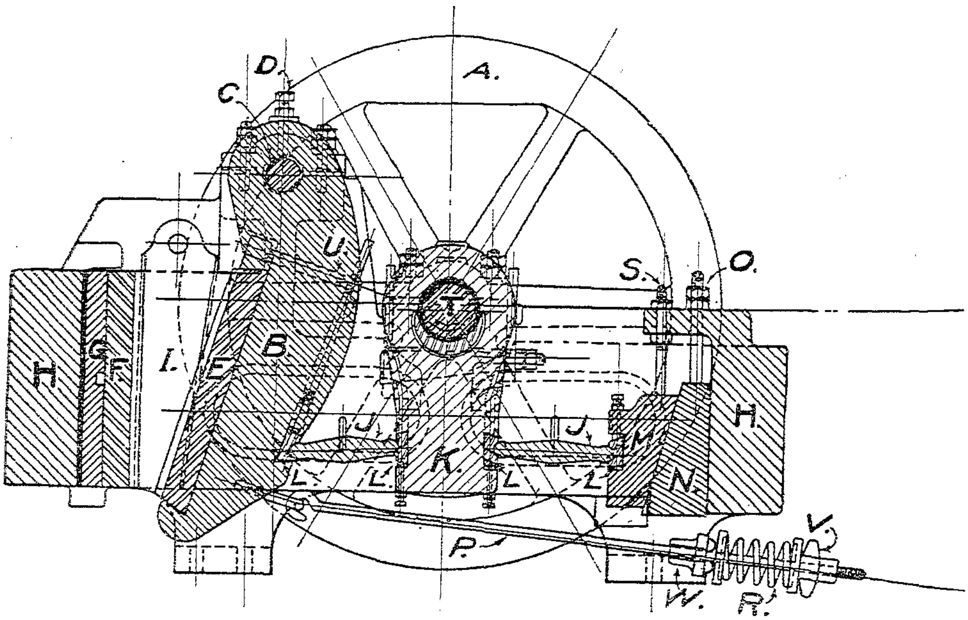


Fig. 9.—Sectional Elevation of the Blake Rock Crusher with Parts Indicated by Letters (after Chalmers & Williams)

A. Flywheel. B. Swing Jaw. C. Swing Jaw Shaft. D. Set Screws for securing Set Jaw to Shaft. E. Swing Jaw Plate. F. Stationary Jaw Plate. G. Stationary Jaw. H. Frame. I. Side Plate. JJ. Toggle Plates. K. Pitman. LL. Steel Bearings for Toggle Plates. M. Toggle Block. N. Wedge Block. O. Wedge Adjusting Bolt. P. Spring Rod. R. Spring. S. Set Screws for Toggle Block. T. Eccentric Shaft. U. Holding down Bolt for Swing Jaw Plate. V. Spring Washer. W. Spring Plate.

The jaw crushers are divided into types according to movement of the swinging jaw: (1) those which are pivoted so as to give the greatest movement on the smallest lumps—Blake type; (2) those which give an equal movement on all sizes; and (3) those which are pivoted below and give the largest movement on the largest lumps—Dodge type. Only the first and third of these types need be considered, since there are very few of the second in use.

The choice between the Blake and the Dodge types of crusher depends largely on the product desired. Since the greatest movement of the swinging jaw on the former is at the bottom and the latter at the top it follows that the Dodge will give the more uniform product. Hence, if it is desired that the crushed stone be as uniform in size as possible the Dodge is the crusher best adapted to the work.

Experiments and practice show that the Blake type crusher will give a larger tonnage for the horsepower used than the Dodge. This is due to the free open discharge of the Blake resulting from the greater movement of the swinging jaw at the bottom. In the Dodge the rock has a tendency to jam or wedge, which condition gives a larger proportion of the fines since the stone is in the crusher for a longer period of time. The difference in capacity per horsepower is also greatly affected by the difference in movement on the larger stone. Suppose of two pieces of stone the same size one is fed to a Dodge crusher and the other to a Blake crusher, both machines the same size. The maximum movement on the piece of stone in the Dodge will be 1 inch in a 7- by 8-inch machine and slightly more than 0.08 in a 7- by 10-inch Blake crusher. It is easily seen that the power necessary in the former is considerably greater than in the latter. The movement is the reverse at the discharge end, but even there the Dodge has a greater minimum movement than the maximum of the Blake. Then it will take more power here to break the stone in the Dodge than in the Blake. If this argument is correct the Dodge requires considerably more power to break a given piece of stone than a Blake. The surplus power is consumed in producing a greater percentage of fines in the Dodge.

The Blake crusher has a greater range of sizes of products than the Dodge, being adjustable by a wedge between one toggle plate and the frame. The Dodge has no such adjustment. This means that the

Blake will have a much wider range of uses. It follows, therefore, that the Blake is the jaw crusher that will find the widest field in working the limestones of the Coastal Plain for agricultural uses, road metal, ballast, etc. Its usual place in the plant is the first crusher.

The following tables give the size, horsepower required, capacity, revolutions of pulley per minute, and the weight of the Blake and Dodge type machines:

BLAKE CRUSHERS

Sizes, Capacities, etc., Compiled from Catalogs

Size of jaw opening	Capacities in tons per hour. Size of product				Amount of H.P required	R. P. M.	Weight
	1″	1½″	2″	2½″			
10″ x 7″	2½	4	5	..	7	250 to 275	6,500
15″ x 9″	6	8	10	12	10	250 to 275	12,000
20″ x 10″	..	10	15	17½	15	250 to 275	15,000
24″ x 12″	..	..	20	25	25	250 to 275	25,000

The capacities given are only approximate and will vary greatly with the stone being worked, that is, a hard brittle stone will go through the crusher much faster than a tough stone.

DODGE CRUSHERS

Sizes, Capacities, etc., Compiled from Catalogs

Size of jaw opening	Capacities in tons per hour to nut size	Approx. H.P. required	R. P. M.	Weight
7″ x 9″	1½ to 2½	6	300	3,250
8″ x 12″	3 to 5	10	300	5,900
11″ x 15″	6 to 8	15	250	13,500

According to Richards[1] the cost of crushing with a Blake breaker varies from 3 to 15 cents per ton under roughly the best and worst conditions. An average would be about 8 cents for a stone that is not too hard to break easily with a fair capacity and labor. Crushing

[1] Richards, R. H., A Text Book of Ore Dressing, 1909, pp. 22-23.

with the Dodge will run slightly higher, due mainly to consumption of more power.

SPINDLE OR GYRATING BREAKERS

There are three general types of these breakers: (1) those which have the greatest movement on the smallest lumps, (2) those which have equal movement on all lumps, and (3) those which have the greatest movement on the largest lumps. Only the first type will here be considered. The second and third types are built only for special purposes.

Examples of the first-mentioned type are the Gates and the McCully breakers. These machines and others closely related are manufactured by a number of firms, but owing to their close similarity the type machine only will be discussed very briefly.

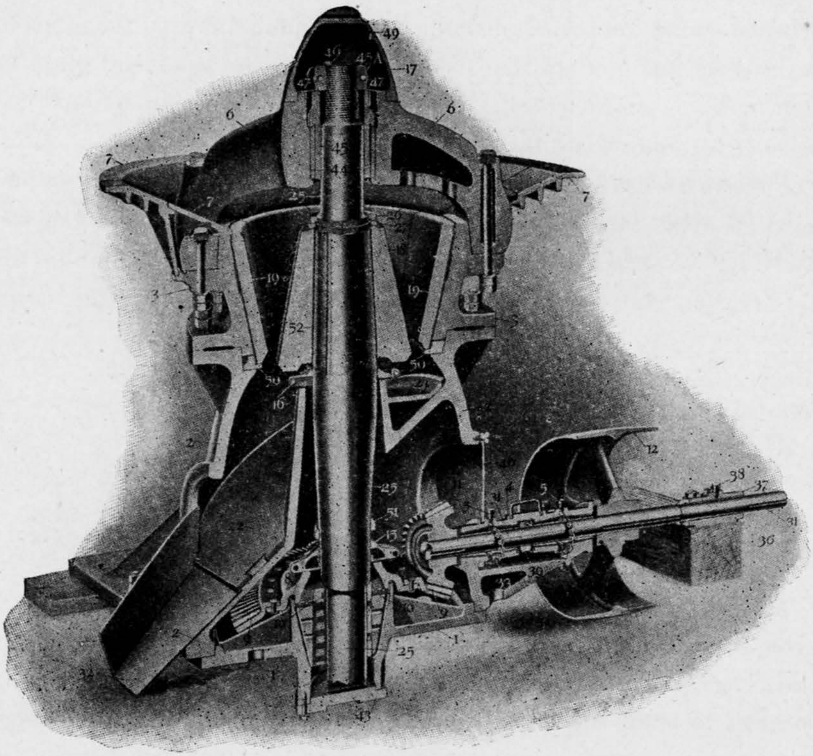


Fig. 10.—Gates Gyratory Breaker (Allis-Chalmers)

The main axis of a gyratory breaker is vertical, see Fig. 10. The main shaft or spindle (25) is hung from the spider (6) at the top of the machine and is given a gyratory motion by an eccentric at the bottom operated by bevel gears. The stone falls into the hopper (7) and thence into the space between the crushing plate (19), an inverted truncated cone, and the head (18), a small vertical truncated cone fixed by keys to the main shaft. Since the top of the spindle is fixed and the lower end moves in a circle, the axis of the shaft describes a long, very acute cone in its gyrations. If the minimum opening between the head and the crushing plate is at a certain point then on the opposite side of the head is the maximum opening. Due to the gyratory motion these positions move continuously around the crushing plate when the machine is in motion. As the stone is being crushed on one side of the machine it is slipping down on the other to be crushed again when the distance between the head and plate at that point is approaching a minimum. This is repeated until the crushed product falls through the discharge chute or spout (32). The crushers are built with this spout on the opposite side of the machine from the drive shaft or at right angles to the axis of the shaft (31). Other makes of machines differ to some extent in the details, but the essential principals of the breakers are the same.

GYRATORY BREAKERS

Size, Capacity, etc., Compiled from Catalog

No.	Dimensions of each of two receiving openings in inches	Capacities in tons per hour			Approx. H.P. required	R. P. M. of driving pulley	Weight
		1½″	2½″	3½″			
1	5 x 20	..	5-9	..	4-6	600	7,100
2	6 x 25	..	7-12	..	6-10	575	10,200
4	8 x 30	15	30	..	14-21	400	22,000
5	10 x 38	..	50	70	22-30	375	32,800
6	12 x 44	..	70	90	28-45	350	48,000

Cost of Crushing with Gyratory Breakers.—The cost of crushing with gyratory breakers as estimated by Richards[1] from catalog data, is shown in the following table:

Estimated Costs of Breaking with Gyratory Breakers

No. of Breakers	0	2	4	6
Size of mouth in inches	4 x 30	6 x 50	8 x 68	12 x 88
Tons broken per hour	3	10	30	62½
Horsepower required	3	8	16	32.5
Cost of breaker	$375	$760	$1,800	$3,300
Costs in cents per ton for oil	0.020	0.020	0.020	0.020
For interest and depreciation	0.169	0.108	0.081	0.071
For power	0.541	0.546	0.288	0.281
For labor	5.556	1.754	0.556	0.267
For wear	0.971	0.971	0.971	0.971
For repairs	0.308	0.308	0.308	0.308
Total costs in cents per ton	7.565	3.617	2.224	1.918

The conditions under which the cost data of the above table were compiled are rather ideal and hence the actual cost might be figured to run slightly higher under ordinary conditions. However, with certain of the soft limestones of the Coastal Plain the cost as given would probably prevail.

Comparison of Jaw and Gyratory Crushers.—Until within recent years the Blake type of crushers were used much more extensively than any other type of machine and probably still are in mining operation. In quarry work, however, the gyratory breakers are used much more generally.

For machines of small capacity the jaw crushers are considerably lighter and cost less and are hence more desirable than the gyratory breakers. For large machines, however, although the first cost of the gyratory breaker is slightly more than for the jaw crushers the former requires less power to operate, takes a larger lump, hence less labor is required in quarrying, and requires less expensive founda-

[1] Richards, R. H., A Text Book of Ore Dressing, 1909, p. 39.

tion and mill structure. The last mentioned item is due to the fact that there is considerably less vibration from a gyratory breaker in that the crushing is continuous, while in the jaw crusher the reciprocating motion means that the stone is being crushed slightly less than half the time. It is evident that under the latter condition a considerable vibration would be imparted to the foundation and building. This allows the gyratory breakers to be set higher in the mill on less expensive structure.

Practice and experiments show that the jaw crushers yield a higher percentage of fines than the other type machine, due to the tendency to pack between the jaws.

The cost of breaking is, according to most authors, in favor of the gyratory breakers, particularly in the large machines.

ROLLS

The roll breaker or coarse crusher is a machine that would, without doubt, give excellent results on the soft limestones of South Georgia. They have large capacities for the weight of the machine, will take large lumps, and are comparatively cheap. The horsepower consumption is claimed to be approximately the same as for the other breakers. There are two types of roll crushers: (1) single roll, and (2) double roll.

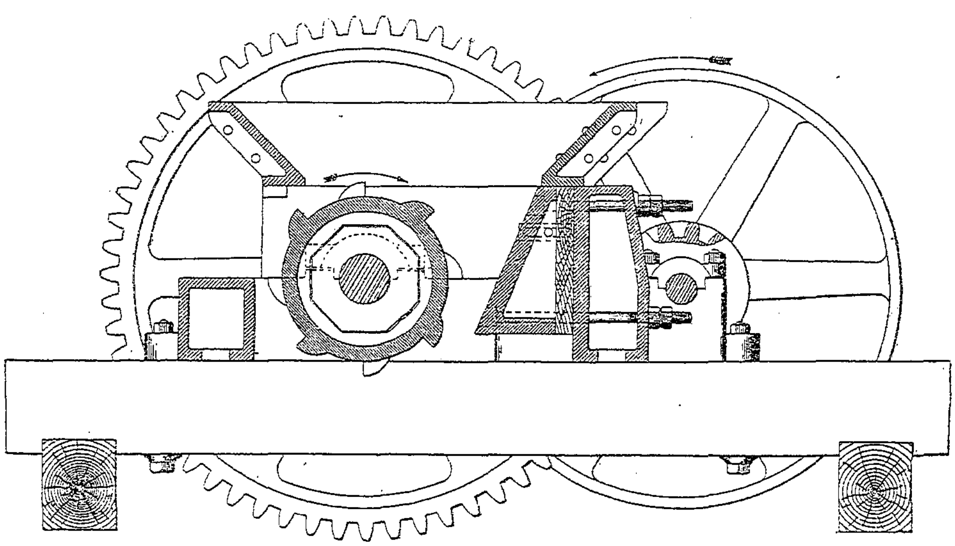


Fig. 11.—McLanahan-Stone Single Roll Crusher

SINGLE ROLL CRUSHERS

Machines of this type are said to be used very successfully in the Florida and Tennessee phosphate fields. The principal parts of the machine are the roll and breaking plate. The roll has a shell of steel or chilled iron with lugs or teeth projecting. The breaking plate may have either a flat or concave surface and holds a position at an acute angle to the perpendicular as shown in Fig. 11. The machines are of very simple construction and require little attention, being practically self-feeding when the bin is properly constructed. The following table gives capacity, size, list price, etc.:

Size, Capacity, etc., of Single Roll Crushers (McLanahan Stone Machine Company)

Size of roll	Average Weight	Price with iron gears (Approx.)	Capacity tons per hour to 2-in. cubes	H.P. required
18 x 16	4,500	$275.00	12	10 to 12
18 x 24	7,200	325.00	20	12 to 15
18 x 30	9,400	400.00	25	15 to 18
18 x 36	10,000	475.00	30	18 to 20
24 x 36	36,000	1,950.00	45	40 to 50

The price with steel gears is about 15 per cent higher in the smaller machines.

DOUBLE ROLL CRUSHERS

These machines are divided into two types, those with corrugated and those with toothed rolls. They are both used mainly in coal washeries, but could probably be applied successfully to the preparation of soft limestones when dry. The rolls are geared together so that when a piece of stone falls between the two it is drawn through and broken. The rolls make from 100 to 150 revolutions per minute.

The corrugated rolls are used mainly when the product desired is less than three-fourths inch. They may be set so that they will grind to the consistency of meal. The toothed rolls have either inserted or cast-in teeth and are used to crush mainly to nut size. It is hardly probable that these machines will find an extensive use in the limestone fields of South Georgia.

GRINDERS AND PULVERIZERS

Grinders and pulverizers are necessary in the preparation of limestone for agricultural uses and for the manufacture of cement. They are also used to pulverize caustic lime and for other purposes. There are a number of different types working on entirely different principles, among which are:

(1) Swing hammer pulverizers
(2) Ring mills
(3) Roller mills
(4) Tube mills
(5) Ball mills
(6) Rolls.

These are the types most likely to be met with in the limestone and allied industries.

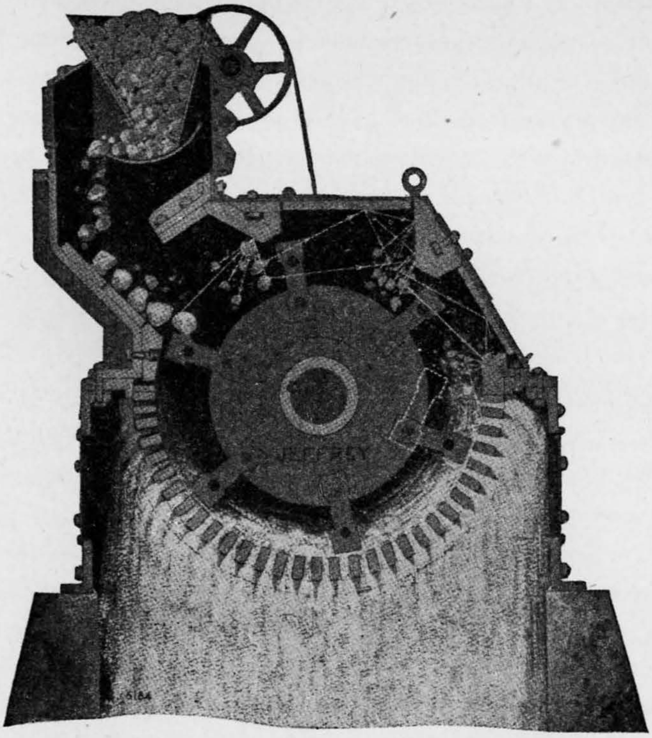


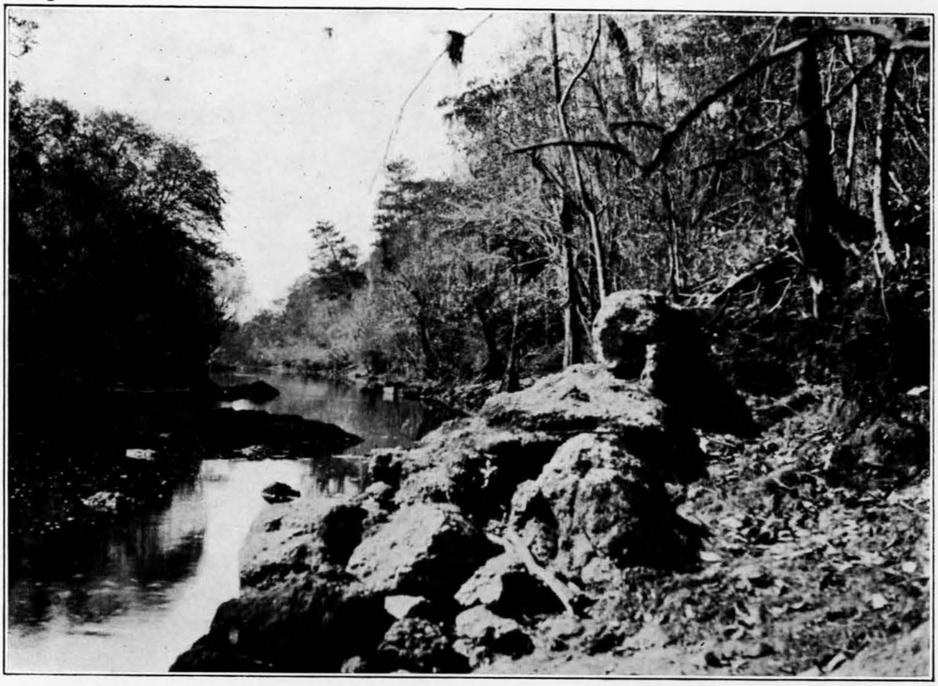
Fig. 12.—Jeffrey Swing Hammer Pulverizer

SWING HAMMER PULVERIZERS

These machines depend upon a blow struck in space to effect the crushing or pulverization of the material fed into the machine. Different types are built by various manufacturers, but the principle is practically the same in all. They will, therefore, be discussed only briefly in a general way. The main features are the beaters or hammers, the breaking plate, and the bar screen. Fig. 12 shows the general construction.

The hammers are hinged to the drum or spider around the shaft usually by steel rods. There are from four to eight rows around the shaft with four to twelve or more in a row, according to the size of the machine. The space between the hammers is usually about the thickness of the hammer, 1½ to 2½ inches. The beaters are of various shapes and sizes, some having detachable heads which receive the wear. One manufacturer makes a machine with a long bar head which fits over all of the hammer arms in one row. The shaft revolves at speeds varying from 1000 to 1800 revolutions per minute. As the stone is fed into the machines it is struck by the beaters, broken and tossed against a breaker plate where it is again broken and rebounds into the path of the beaters and is again tossed against a breaker plate and further comminuted. The breaker plates are usually of steel and set at such an angle that the stone will rebound into the path of the beaters in the direction of rotation as shown in the figure. These plates are replaceable. When the stone reaches the last screen it is rather finely crushed and is here subjected to a grinding action. The bars are set from one-fourth to one-eighth inch apart at the top and are so shaped that the distance between the bottom edges is greater so as to prevent packing. Owing to the high speed of the machine ball-bearings are usually used on the main shaft.

The feed for a swing hammer pulverizer usually comes from a jaw or gyratory crusher in sizes varying from 1 to 3½ inches. Larger stone is often fed, but this is not advisable. The capacity of the machine depends upon the size of the feed stone, the speed of the beaters,



A. EXPOSURE OF LIMESTONE OF THE CHATTAHOOCHEE FORMATION AT STONY LAKE BLUFF, WITHLACOOCHEE RIVER, 7 MILES SOUTHEAST OF QUITMAN, BROOKS COUNTY.

B. EXPOSURE OF CHATTAHOOCHEE LIMESTONE IN BANK OF WITHLACOOCHEE RIVER, NEW BRIDGE (OR HORN BRIDGE) 3 MILES BELOW THE VALDOSTA SOUTHERN RAILROAD BRIDGE, LOWNDES COUNTY.

and the size of the product desired. Dry stone crushes much more rapidly than moist stone.

The following tables show data compiled from several catalogs of different manufacturers:

Data on Swing Hammer Pulverizer Compiled from Catalog

Size of feed	Diameter of mill	Capacity tons per hour dry stone		H.P.	Speed, rev. per min.	Weight	Approx. Price
		12 mesh	20 mesh				
1″	18″	¾-1½	½-1	10-12	1,800	2,500	$300
1½″	26″	2-4	1-3	15-20	1,600	4,000	400-900
1½″	26″	5-6	3-5	20-25	1,600	5,000	1,000
2″	26″	6-8	5-6	30-35	1,600	6,500	1,200
2″	40″	10-12	8-10	50-60	1,100	12,000	1,500
2½″	40″	13-15	10-13	65-75	1,100	14,000	2,100

The minimum capacity is for hard stone and the maximum for soft. The size of the feed may be increased, but it will curtail the capacity. These machines are said to deliver a product 95 per cent of which will pass 20 mesh.

Test on Hard Limestone with Swing Hammer Pulverizer

Bar screen opening.	Capacity in tons per hr.	Speed	Per cent passing screen indicated			
			10 mesh	20 mesh	40 mesh	100 mesh
⅛″	8 to 10	1,100	99%	95%	85%	60%
No screen	40 to 50	1,060	80%	63%	42%	19%

The stone fed was in pieces 2 to 3 inches in diameter. The first product is finer than necessary for agricultural purposes, while the second is scarcely fine enough. The mesh of a screen is the number of openings per linear inch. Thus a 10-mesh screen has 10 openings per linear inch or 100 openings per square inch. A standard size wire is used for each mesh.

No cost data could be secured on the operation of swing hammer machines. A fairly accurate estimate can be made, however, by calculating the cost of power per ton, labor, and interest on investment and then allowing for oil, depreciation and repairs. Where automatic feeders are used no labor is necessary, provided the bins and chutes are properly built.

ROLLER MILLS

These mills are of several types, but all are simple, the material being fed between high-speed steel or iron wheels rolling on a steel die. Three of the better known of these machines are the Chili mill, the Huntington mill and the Griffin mill.

The Chili mill has two or more vertical wheels which roll on a circular die around the main shaft. The die is set in a pan into which the ore or stone is fed directly onto the die. The sides of the pan are so made that the centrifugal thrust is consumed in grinding the material. A 6-foot mill has a capacity of about 100 tons of fairly soft ore per 24 hours, reducing the same from one-fourth-inch size to 30 or 40 mesh. The necessary fineness of the feed and the small capacity will eliminate it from use in the limestone fields. They are used primarily for the fine grinding of ores.

The Huntington mill is very similar to the Chili mill, except that the rollers are horizontal. They are used largely in the fine grinding of gold ores.

The Griffin mill consists of a roller suspended from a vertical axis rolling upon the inside of a circular die. This machine has been used to some extent in grinding phosphate rock and limestone for Portland cement. A 30-inch mill will crush from 1½ to 4 tons of stone per hour, from 1½ inches to 40 mesh, utilizing 15 to 25 horsepower. These results compare very favorably with those of other machines, but the cost of wearing parts per ton of product is comparatively high.

TUBE MILLS

A Tube mill consists of a long steel cylinder with cast iron ends. The inner lining of the mill is so grooved that the flint or quartz pebbles with which the mill is charged will fit in the grooves and relieve the steel or iron lining of wear. Considerably more of the pebbles are placed in the tube than will fill the grooves. These balls act as the grinders when the cylinder is revolved on the iron rollers beneath the cylinder. The tube slopes slightly towards the discharge end so that as the stone is pulverized it moves toward and finally through the discharge opening. The crushing is effected by the pebbles and feed being carried up as the tube revolves and then falling to the bottom. These mills are used very extensively in grinding cement clinker and limestone. One great objection to the mill is that the feed should be comparatively fine, 8-mesh or finer. The capacity is comparatively small.

BALL MILLS

The Ball mill is somewhat similar in principle to the Tube mill, but steel balls instead of quartz pebbles are used and the length of the cylinder is usually less than the diameter. This mill will take a feed up to 2½ inches. The machine is of small capacity compared to the swing hammer mills, but gives a finer product. The cost per ton of wearing parts is rather high. The Ball mill is most extensively used in the metallurgical treatment of gold ores. They are also used to some extent in cement plants.

ROLLS

Fine crushing rolls consist of two steel or iron cylinders revolving upon parallel shafts so placed that when a piece of stone falls between the rolls it will be drawn through and crushed to the size of the openings. Rolls are of comparatively small capacity and will find little or no use in crushing the limestones of South Georgia. They are used mainly in the treatment of brittle ores where a minimum of fines are desired.

SCREENS

In the preparation of crushed stone for concrete aggregate, ballast, etc., it is always necessary to size the product. This is done by screens. There are three general types in use, each of which has its own field to cover—(1) grizzlies or bar screens, (2) revolving screens, and (3) shaker screens.

GRIZZLIES

Grizzlies or bar screens are used for separating coarse from fine stone and are usually placed so that the discharge from the preliminary crusher feeds directly over them. They are usually built of stationary iron bars, placed a definite distance apart, according to the products desired. The material that will not pass through the openings is called the over-size and that going through the under-size. The screens are placed at such an angle that the stone will slide over them by gravity slowly enough to allow complete separation. Different materials require different angles of slope. The grizzlies are placed so that the stone will slide along rather than across the bars of which it is built. The lateral flexibility of the bars is taken care of by bolts running across the grizzley through holes in the bars with space thimbles placed on the bolts between the bars.

REVOLVING SCREENS

Revolving screens or trommels are usually made of a tube or cylinder of perforated sheet steel with a steel shaft running through the center. Suitable gears or pulleys by which the screen is revolved are placed at one end. The discharge end is lower than the feed end so that as the screen revolves the over-size stone will work its way to the discharge end. When several sizes of stone are desired the screen is made up in sections, the first section having the smallest perforations and the last section the largest. The bin below the trommel is built in as many compartments as there are sizes of stone produced.

The capacity of a trommel depends upon the size of the cylinder and the speed in revolutions per minute. Where only one size perforations are used the trommel is usually 3 or 4 feet in diameter and 6 to 10 feet long. Where several size holes are used the screen is considerably longer, frequently 20 feet or more. There is, of course, a maximum speed that can be used since above this the centrifugal force would prevent the stone from moving toward the discharge end.

SHAKING OR PULSATING SCREENS

Shaking or pulsating screens are used where a product of one-fourth to one-half inch is desired. The first under-size stone from the revolving screen is fed onto the shaker screen. If the feed is all less than one-half inch and the openings in the shaker one-fourth inch the over-size product will naturally be one-fourth to one-half inch in diameter. If pulverized stone is also desired the under-size is fed to a pulverizer.

The shaker screen for the above size product is usually made of wire. The discharge end is lower than the feed end so that when the pulsating motion is imparted to the screen by a suitably arranged eccentric the stone works its way gradually down and is discharged.

BUCKET ELEVATORS

Where a crushing or grinding plant is built on level ground it is nearly always necessary to elevate the stone from the discharge of one machine to the feed of another. This is done usually by elevator buckets. These buckets are built of sheet steel and attached to double or single chains or belting. The chains pass over sprocket wheels or pulleys at the top or discharge point of the elevator and at the bottom or loading point. The capacity is governed by the size and number of the buckets and the speed of the chain and can be readily calculated.

CONVEYORS

It is frequently desirable in a stone crushing plant to convey certain products from one point to another along a horizontal or slightly sloping line. This is done by two types of conveyors, (1) the belt conveyor and (2) the screw or helical conveyor.

The belt conveyor is a wide, endless rubber, canvas, or leather belt driven by and running over pulleys. In order to lessen the tension on the belt it is supported along its course by sets of rollers at short intervals. Each set is usually made up of four rollers, two horizontal ones beneath the center of the belt and one under either edge, set at an angle so as to make a trough of the belt to prevent the stone from rolling off. These belts are frequently used for charging storage bins. When a number of bins are used with the belt passing across each and it is necessary to dump the load before the end of the conveyor is reached, a suitable machine for this purpose is built. The belt goes over a pulley at the top of the dumping carriage and then doubles back and passes around another pulley. The stone is dumped below from the upper pulley into a chute that feeds into the bin.

A helical or screw conveyor is very similar in design to a common wood auger. This screw fits closely into a semi-circular trough and as it is revolved conveys the stone from the feed to the discharge end. The conveyors are from 6 to 12 inches in diameter. The capacity depends upon the size of the screw and the speed. Fine material is more satisfactorily handled than coarse.

DRYERS

When a damp limestone is to be ground for agricultural or other uses it is frequently more economical to dry the stone before attempting to pulverize it. The damp stone is not as friable or brittle as the dry and hence is not as easily broken. Also, the moisture causes the screen to be clogged and thereby reduces the capacity. The moisture is also objectionable in the product, since it adds weight and hence freight charges per ton of actual stone.

The rotary dryer is the most common in use. It consists of a steel, fire-brick lined cylinder about 4 feet inside diameter and 25 to 40 feet in length. The kiln slopes gently toward the discharge end so that as it revolves the stone works its way to the discharge opening. A fire-box at the lower end supplies the heat. The gases from the burning coal or wood pass through the kiln and out through a stack at the upper or feed end.

The capacity depends upon the size of the kiln, the number of revolutions per minute, the size of the fire and the amount of moisture in the stone.

KILNS

Kilns are used in the limestone products industries in calcining limestone for lime and in the manufacture of cements. The vertical or shaft type lime kilns are discussed briefly under the heading "The Manufacture of Lime," and will, therefore, be omitted here. Revolving kilns are used very extensively in the manufacture of Portland and other cements, and lime when it is to be sold as hydrated lime.

These kilns are very similar in construction to the dryers described above, but are much larger. The outer shell is of sheet steel and the lining fire-brick. They are 6 or 7 feet in diameter inside and 60 to 200 feet in length. The kiln revolves on rollers, being turned 2 or 3 times per minute by power applied through gears. The discharge end is slightly lower than the feed end so that the cement mixture and final clinker will work its way to the discharge. The heat is supplied by coal dust usually, but also natural gas or crude petroleum. The fuel is blown in at the lower end of the kiln and burns therein. The gases go out through the feed end into a stack and hence to the air or through suitable pipes to be used in dryers.

Small kilns of this type are used in calcining limestone when it is to be made into hydrated lime or ground caustic lime. The limestone before being fed into the kiln must be crushed to a small size to insure thorough calcination, hence lump lime cannot be burned in this type of kiln.

PLANTS FOR CRUSHING AND GRINDING LIMESTONE

The type of plant and the machines to be installed therein to work the limestone of a given deposit depends upon the character of the stone and the products desired. It, therefore, seems desirable to discuss briefly several plants designed to work under different conditions and for different purposes. Since the individual machines have been described on previous pages they will only be mentioned as parts of the plants. A short discussion of three plants seems sufficient to give an idea of the methods of preparing the limestone for different purposes. The plants taken up will be as follows:

(1) A plant of 1½ to 4 tons per hour capacity of agricultural limestone from hard or soft limestones.

(2) A plant of 15 tons per hour capacity of agricultural limestone from hard or soft stone.

(3) A plant for preparing crushed stone for ballast, road metal and concrete aggregate and ground limestone for agricultural uses. Total capacity 50 tons per hour of all products.

The above sizes and types of plants are those which are most likely to be used in developing the limestone resources of the Coastal Plain of Georgia.

A Plant of 1 1/2 to 4 Tons per Hour.—A plant of this size is for the purpose of supplying ground agricultural limestone for local or individual use. Several manufacturers have on the market single machines which will reduce to an 8-mesh product in one operation, stone which will just enter a 7-inch by 9-inch opening. Such a machine requires about 15 horsepower and will yield 1½ tons per hour. Where this capacity is sufficient to supply the need this is the ideal plant for local farm use.

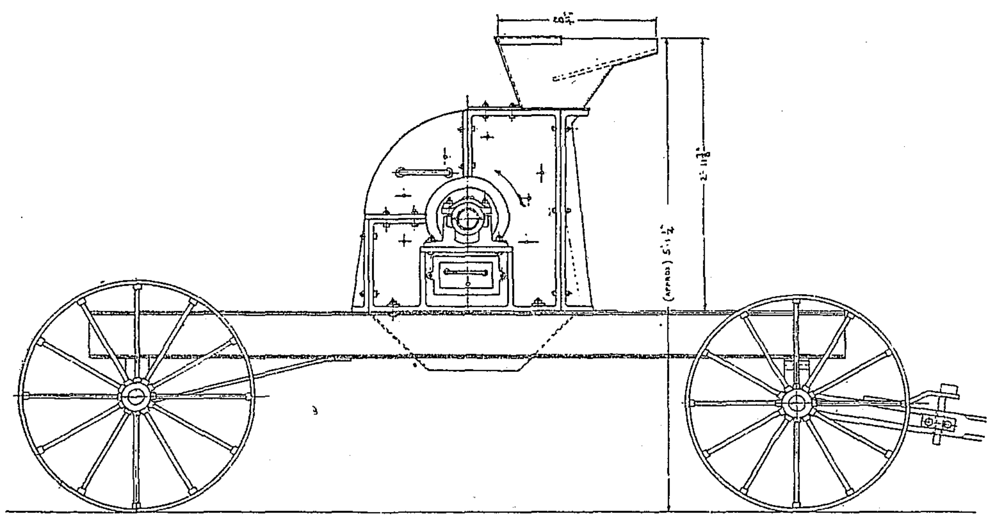


Fig. 13.—"Allis-Chalmers Hummer" Pulverizer—Mounted on Steel Truck

When greater capacity is desired a more elaborate plant is necessary. The same pulverizer may be used, but instead of feeding the large stone to it direct it is first run through a preliminary crusher and reduced to about 2-inch size. This increases the output of the pulverizer to 3 to 4 tons of ground limestone per hour.

Flow Sheet of Plant Having Capacity of 3 to 4 Tons per Hour of Agricultural Limestone

Quarry
↓
Crusher (1)
↓
Elevator bucket (2)
↓
Pulverizer (3)
↓
Conveyor (4)
↓
Storage or wagon.

The crusher (1) may be either a jaw, gyratory, or other type. A Blake type jaw crusher would probably give the best results, especially on a hard stone. The stone is delivered from the quarry to the machine in sizes that will enter a 9- by 12-inch opening. After being reduced by the crusher it is raised by the bucket elevator (2) to the feed opening of the pulverizer (3). A swing hammer type machine is probably best suited for this work. The final product from the pulverizer is conveyed to storage or wagon by a screw or bucket elevator (4). This conveyor may be dispensed with, but if so a man is necessary to keep the finished product back from the discharge of the machine, unless it is hauled away as rapidly as ground.

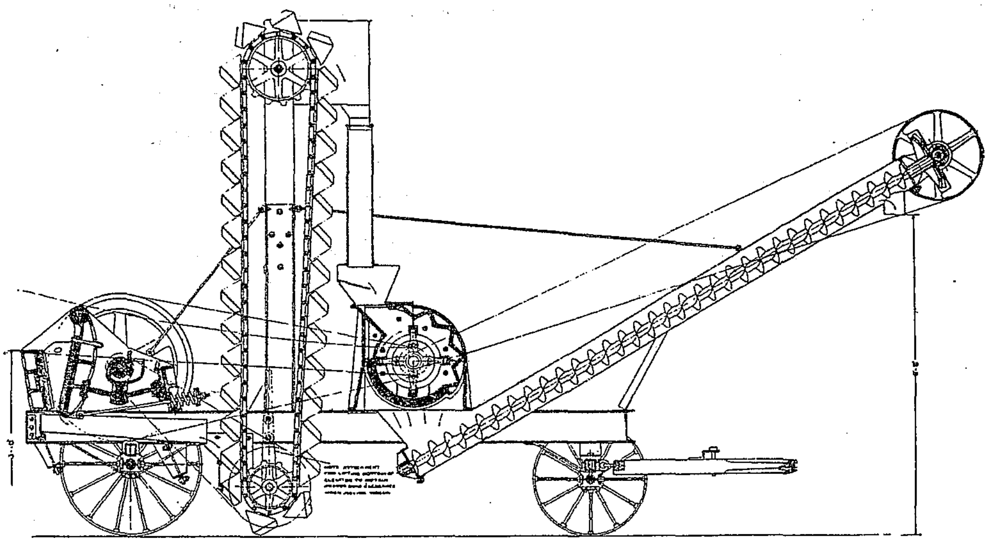
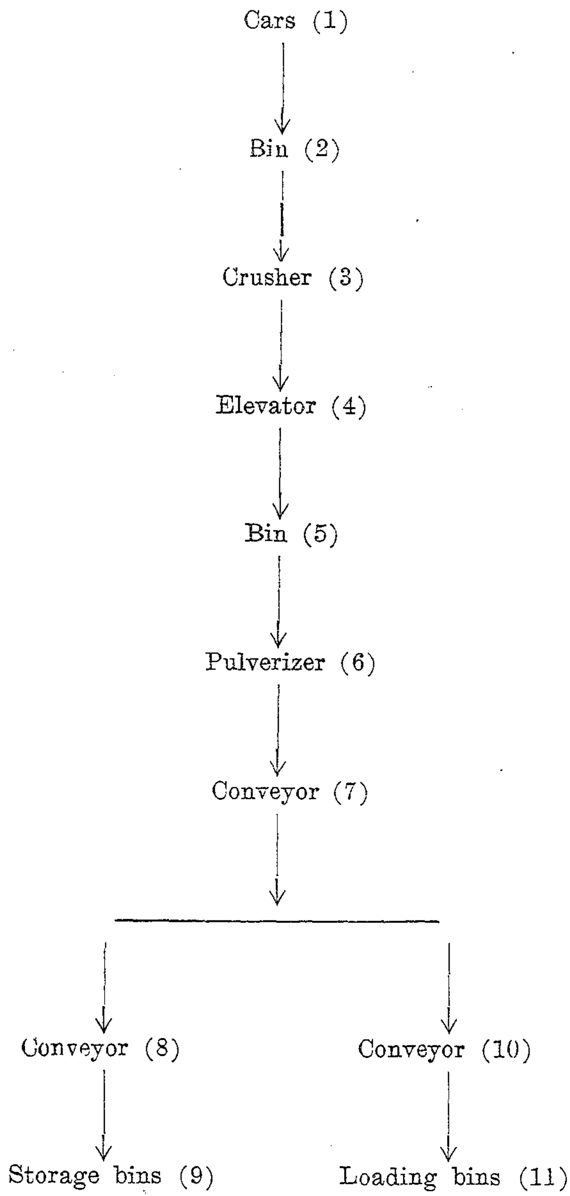


Fig. 14—Allis-Chalmers L.B.H. Hummer Crusher and Pulverizer

The single machine or crusher and pulverizer plants may be set either on permanent foundations or mounted on steel trucks so that they can be moved from place to place. Power may be obtained from steam or gasoline engines. Fifteen horsepower is necessary to operate the single machine and 20 horsepower for the more elaborate plant.

A Plant of 15 Tons per Hour Capacity of Agricultural Limestone from Hard or Soft Stone.—A plant of this capacity is designed primarily to furnish ground limestone on a more extensive scale. The flow sheet of such a plant is as follows:

Flow Sheet of Agricultural Limestone Plant with Capacity of 15 Tons per Hour



The stone is loaded at the quarry in tram cars (1) of surface or overhead type and dumped automatically into the bin (2). This bin should have a capacity of at least several cars so that the haulage and quarry work will not be held up when the crusher is stopped for a short time or vice versa. The stone feeds from the bin into the crusher mouth (3). This crusher may be of the jaw, gyratory, single roll, or other types. The gyratory type is most generally used in stone-working plants. The crusher should be of about 20 tons capacity of stone to 2- or 2½-inch size. This slight excess capacity is advisable in order to assure a steady feed to the pulverizer when the crusher is shut down for a few minutes occasionally for various reasons. About 15 horsepower is required to operate the machine.

The crushed stone is taken from the crusher discharge by the bucket elevator (4) and delivered to the feed bin (5) of the pulverizer. The bin should be of sufficient size to hold enough stone to operate the pulverizer for a short period of time if it is necessary to stop the crusher for any reason. This assures a steady production. The bin feeds automatically to the pulverizer (6). This machine may be of the swing hammer type, ring mill, ball, or tube mill, or others. This depends largely upon the type of stone and first cost of the machine. The swing hammer pulverizer would probably give very satisfactory results on the soft limestones of South Georgia. A 15-ton per hour capacity machine requires about 75 horsepower to operate it.

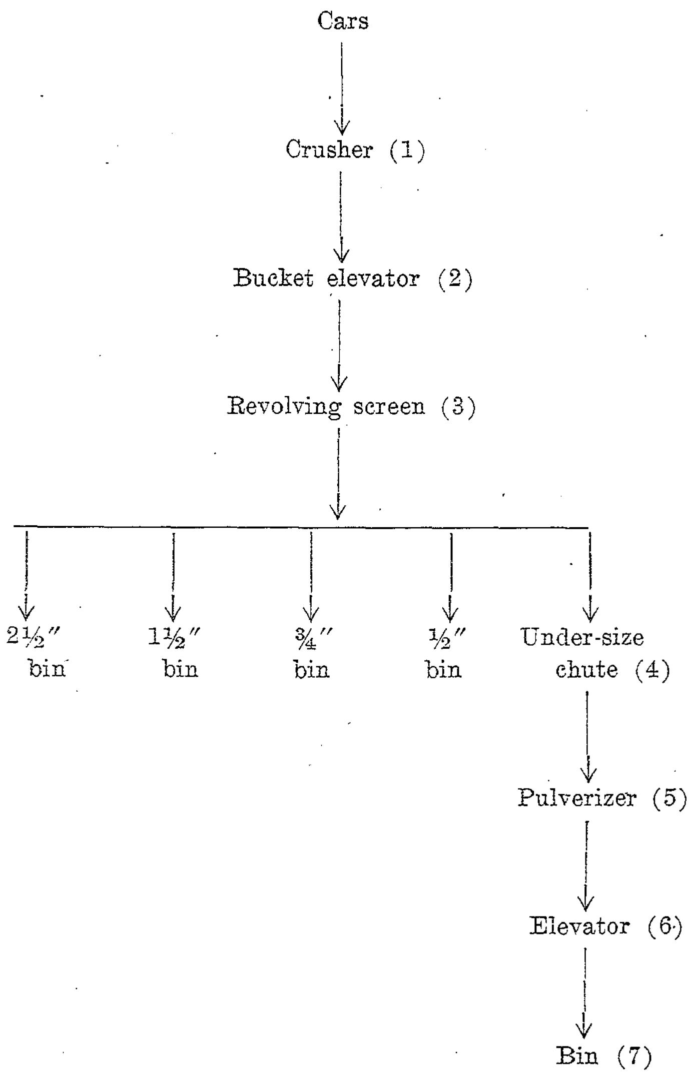
The finished product discharges into a conveyor (8 and 10) to be carried to storage bins or loading bins (9 and 11). Since the demand for the product is largely in the fall and winter months it may be necessary to have large capacity storage bins in order to supply the demand during the "season."

Although dry stone is considered in the capacities of the machines no means of drying has been put in the flow sheet. It is quite probable that drying will be necessary before the stone can be pulverized economically. In this case a mechanical dryer must be installed.

A power plant consisting of a 100-horsepower boiler and a 100-horsepower high-speed engine is sufficient to operate the plant.

A Plant for Preparing Crushed Stone for Ballast, Road Metal, etc., Total Capacity 50 Tons per Hour of all Products.—This type plant would be designed to supply a comparatively large area with such materials as mentioned. A hard limestone is, of course, necessary to give good crushed stone products. The flow sheet would be as follows:

Flow Sheet of Crushed Stone Plant of 50 Tons Hourly Capacity



The quarry stone is dumped into a 50- to 70-ton crusher (1) and reduced to 3-inch size and smaller. Gyratory crushers have found preference in this work, but other types may be employed with practically as good results. About 30 horsepower is necessary to reduce the stone. A bucket elevator (2) receives the stone from the discharge and lifts it to the revolving screen (3), usually at the top of the mill. The screen is built up in three sections, having 2½-, 1½-, and three-quarter-inch perforations respectively. Surrounding the three-quarter-inch section there is an outer jacket having one-half-inch perforations. The stone is fed in at the upper end of the screen onto the three-quarter-inch sections. All smaller than this size fall through onto the one-half-inch screen. The under-size on this screen falls through and the over-size goes out at the lower end. The over-size from the three-quarter-inch screen goes onto 1½-inch section and is further separated and so on to the end of the screen. Suitable bins are built beneath the revolving screen to hold the sized products. Chutes leading from these bins dump directly into cars, wagons or onto a conveyor belt which conveys the stone to larger storage bins.

The under-size from the ½-inch screens works by gravity (4) into a pulverizer (5). The size of this pulverizer depends upon the quantity of the ground stone desired. A 10- to 15-ton machine will take care of the fine material ordinarily. If a larger capacity is desired chutes should be built so that the product from the crusher or sized-stone bins can be fed into the pulverizer.

A 125-horsepower boiler and engine will produce sufficient power to operate the plant unless a large pulverizer is desired.

APPENDIX A

LIMESTONE QUARRIES OF NORTH GEORGIA

At the present time all of the limestone, dolomite and marble quarries being operated in Georgia are in the northern part of the State. The stone is of Paleozoic age and varies in texture from granular limestone and dolomite to coarsely crystalline marble. The following brief descriptions are of quarries producing crushed and pulverized stone and lime during the Fall of 1915.

Deal Lime Works.—The quarries and kilns of the Deal Lime Works are located 2 miles south of Gainesville, Hall County, near the Southern Railway. There are three quarries on the property, only one of which (Quarry No. 2) was being operated at the time of the writer's visit. The stone is a hard, light dove colored, finely crystalline, dolomitic limestone. All of the stone quarried is used in the manufacture of lime. There are two lime kilns on the property, one of 75 and the other 125 barrels daily capacity. The smaller kiln has not been operated in several years.

Analyses[1] of Limestones from Deal Lime Works, near Gainesville, Georgia

Quarry No.	2	3
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)	trace	.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
Total	100.00	100.00
Calcium carbonate ($CaCO_3$)	50.00	53.61
Magnesium carbonate ($MgCO_3$)	33.92	37.76
Total carbonates	83.92	91.37

The Art Marble Company's plant and quarry are located at Gartrell, Gilmer County, on the Louisville and Nashville Railroad. The stone worked is a fine grained, white marble which occurs near the

[1] Maynard, T. Poole, Limestone and Cement Materials of North Georgia: Bull. Ga. Geol. Survey, No. 27, 1912, pp. 112-114.

base of the Murphy Marble formation. Both high-calcium and high-magnesian stones are worked. The following analyses are of the two varieties of stone:

Analyses[1] of Marble from Art Marble Company

Lime (CaO)	53.00	39.10
Magnesia (MgO)	1.54	11.30
Alumina (Al_2O_3) } Ferric oxide (Fe_2O_3) }	1.44	2.06
Phosphorus pentoxide (P_2O_5)	trace	trace
Silica (SiO_2)	1.00	4.60
Undetermined	43.02	42.94
Total	100.00	100.00
Calcium carbonate ($CaCO_3$)	94.60	69.80
Magnesium carbonate ($MgCO_3$)	3.23	23.70
Total carbonates	97.83	93.50

The marble is quarried and then prepared by crushing and pulverizing for flooring material, roofing stone, road dressing and agricultural purposes. The plant has a capacity of about 30 tons per day of agricultural limestone.

The Southern States Marble Company at Whitestone, Pickens County, quarries finely crystalline marble of the Murphy formation. The plant is equipped for preparing crushed marble for flooring, roofing and other uses and pulverized stone for road dressing and agricultural purposes. A tube mill of 30 tons daily capacity is used for pulverizing.

The Whitestone Marble Company's quarry and plant are located at Whitestone, Pickens County, on the Louisville and Nashville Railroad. The stone worked is a fine grained, white, magnesian marble. It is crushed to three sizes for flooring and roofing stone, while the under-size from the smallest screen opening is pulverized for road

[1] Op. cit., p. 120.

dressing and agricultural uses. The plant has a capacity of 150 tons of pulverized stone per day.

An average of three analyses from different strata in the mine is as follows:

Average Analysis of Marble from Whitestone Marble Company

Lime (CaO)	33.43
Magnesia (MgO)	17.05
Alumina (Al_2O_3) } Ferric oxide (Fe_2O_3) }	1.35
Phosphorus pentoxide (P_2O_5)	trace
Silica (SiO_2)	4.29
Undetermined	43.88
Total	100.00
Calcium carbonate ($CaCO_3$)	59.70
Magnesium carbonate ($MgCO_3$)	35.80
Total carbonates	95.50

The Ladd Lime & Stone Company's quarry and plant are located on Ladd Mountain, 2 miles southwest of Cartersville, Bartow County. Dolomite of the Knox formation is quarried and crushed for use as ballast, road metal, concrete aggregate and other purposes. The under-size from the screen having the smallest opening is pulverized in a Sturtevant ring mill and sold for agricultural purposes. The plant has a capacity of 300 tons per day of agricultural limestone

The following analyses are of samples of stone from the quarry and storage bins:

Analyses of Dolomite from Ladd Lime & Stone Company, Cartersville

Soda (Na_2O)	trace	.04	.10
Potash (K_2O)	trace	.06	.06
Lime (CaO)	30.00	29.04	31.96
Magnesia (MgO)	20.00	18.16	18.70
Alumina (Al_2O_3) / Ferric oxide (Fe_2O_3)	1.20	1.52	1.20
Silica (SiO_2)	3.05	7.89	2.66
Undetermined	45.75	43.29	45.32
Total	100.00	100.00	100.00
Calcium carbonate ($CaCO_3$)	53.55	51.86	57.07
Magnesium carbonate ($MgCO_3$)	42.00	38.14	39.27
Total carbonates	95.55	90.00	96.34

The first and third analyses are of average samples from the face of the quarries while the second is of the agricultural limestone in the storage bins.

The Piedmont Portland Cement Company's quarry and plant are located at Portland, on the Seaboard Air Line Railroad, 5 miles north of Rockmart. The quarry was originally opened for the manufacture of lime. Some years later, however, a plant was installed for the manufacture of Portland cement but was operated for a short while only. At the present time crushed stone for ballast, road metal and concrete aggregate, and pulverized stone for agricultural uses is prepared. The plant has a capacity of 300 tons per day of this last mentioned product. The limestone quarried belongs to the Chickamauga formation and consists of both high-calcium and high-magnesian limestone. The following analyses are of the two types of stone:

Analyses[1] of Limestone from Piedmont Portland Cement Company

Soda (Na_2O)	.14	.05
Potash (K_2O)	.17	.25
Lime (CaO)	50.12	33.22
Magnesia (MgO)	1.81	12.68
Alumina (Al_2O_3) } Ferric oxide (Fe_2O_3) }	1.92	2.60
Phosphorus pentoxide (P_2O_5)	.01	.02
Silica (SiO_2)	3.36	8.98
Undetermined	42.47	42.20
Total	100.00	100.00
Calcium carbonate ($CaCO_3$)	89.52	59.40
Magnesium carbonate ($MgCO_3$)	3.80	26.60
Total carbonates	93.32	86.00

[1] Maynard, T. Poole, Limestone and Cement Materials of North Georgia: Bull. Ga Geol. Survey, No. 27, 1912, p. 147.

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