GEOLOGICAL SURVEY OF GEORGIA
S. W. McCALLIE, State Geologist

BULLETIN NO. 37

PRELIMINARY REPORT

ON THE

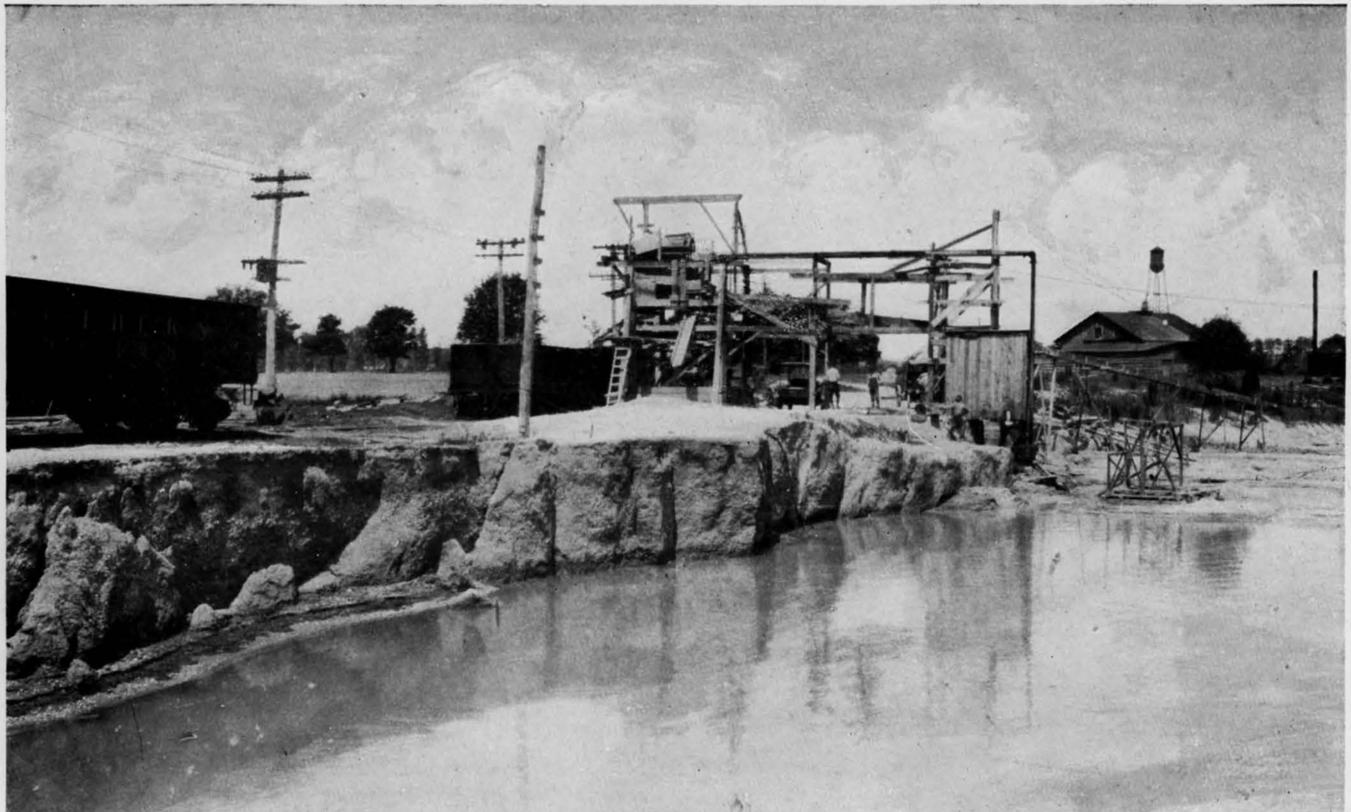
SAND AND GRAVEL DEPOSITS

OF

GEORGIA

BY
L. P. TEAS
Assistant State Geologist

1921
BYRD PRINTING COMPANY,
ATLANTA, GA.



PLANT AND PIT OF THE GEORGIA SAND & GRAVEL COMPANY,
AUGUSTA, RICHMOND COUNTY

THE ADVISORY BOARD

OF THE

Geological Survey of Georgia

IN THE YEAR 1921

(Ex-Officio)

His Excellency, HUGH M. DORSEY ---------- Governor of Georgia
President of the Board

HON. S. G. McLENDON ---------- Secretary of State

HON. W. J. SPEER ---------- State Treasurer

HON. W. A. WRIGHT ---------- Comptroller-General

HON. R. A. DENNY ---------- Attorney-General

HON. J. J. BROWN ---------- Commissioner of Agriculture

HON. M. L. BRITTAIN ---------- Commissioner of Public Schools

LETTER OF TRANSMITTAL

Geological Survey of Georgia,
Atlanta, Jan. 15, 1921.

To His Excellency, HUGH M. DORSEY, *Governor, and President of the Advisory Board of the Geological Survey of Georgia.*

SIR: I ave the honor to transmit herewith the report of Mr. L. P. Teas, Assistant State Geologist, on the Sand and Gravel Deposits of Georgia to be published as Bulletin No. 37 of this Survey.

Very respectfully,
S. W. McCALLIE,
State Geologist.

TABLE OF CONTENTS

TABLE OF CONTENTS

TABLE OF CONTENTS

TABLE OF CONTENTS

TABLE OF CONTENTS

ILLUSTRATIONS

FIGURES

MAPS

SAND AND GRAVEL DEPOSITS OF GEORGIA

NATURE, CLASSIFICATION AND PROPERTIES OF SAND AND GRAVEL

SAND

Sand consists of fine particles of crushed or worn rock. The term sand refers particularly to the condition and size of the grains making up the material rather than to their chemical or mineralogical composition. Thus we may have silica sand, calcite sand, or black sand, provided the size of the grains falls within certain arbitrary limits. We may define sand as an incoherent material made up of grains ranging from $\frac{1}{150}$ of an inch to $\frac{1}{4}$ inch in size. Unconsolidated material, whose grains lie between $\frac{1}{100}$ and $\frac{1}{250}$ of an inch, is known as silt; and if the grains fall below $\frac{1}{250}$ of an inch we have clay or mud.

GRAVEL

When the grains of any natural, unconsolidated substance become larger than $\frac{1}{4}$ inch in diameter, the term gravel is applied to them. Like sand, gravel may be made up of pebbles of quartz, chert, limonite and many other substances. As a rule gravels consist of harder rock types such as quartz, flint, granite, etc., since they better resist constant attrition. The pebbles are usually characteristically rounded, or at least sub-angular, from the rolling and tumbling they have been subjected to. Usually, considerable sand and clay are included with the pebbles so that the material may be known as a *sand gravel* or a *clay gravel.* When the pebbles attain 4 or 5 inches in diameter the term *cobble* is applied to them. *Boulder gravel* refers to material consisting of boulders ranging from 10 inches to 4 feet or more in diameter.

ORIGIN

The grains and pebbles of which sand and gravel are composed have been derived from the mechanical disintegration and chemical decomposition of rocks. Later concentration of the particles by water or wind produces the deposits as we know them today. The weathering processes which are constantly at work upon the rocks are of two types, mechanical and chemical.

Mechanical action.—Water that has been introduced into rocks through pores or joints, upon freezing exerts an expansive force of 150 pounds to the square inch. Such pressure breaks off large masses of rock which in time are broken up into smaller pieces and finally crumble into sand. In arid regions, wide daily extremes of temperature set up strains in minerals having unequal rates of expansion, causing both the minerals themselves and the rocks which they form to disintegrate into sand. Even in ordinary climates the unequal expansion of rock minerals is an important factor in sand production, though not so striking as in desert regions. Pebbles and rock fragments, carried by streams whose velocities in flood periods are often capable of moving boulders exceeding a foot in diameter, exert a constant abrasive action on the stream bed and upon each other, producing much sand as they roll down-stream.

The gouging action of rock fragments held by glacial ice as it passes over the surface is one of the most effective means of rock disintegration in high latitudes and in lofty mountain areas. The extensive gravel and sand deposits of our northern states are largely of glacial origin. The materials were first produced by the grinding action of the ice and later heaped into deposits as it advanced, or concentrated by water flowing from the ice as it melted. The expansion of tree roots and the action of burrowing animals also aids in breaking up the rock into fragments.

In all rock disintegration the softer and less resistant rocks or minerals composing the rocks, such as calcite, hornblende, and similar minerals, are more rapidly broken up and ground into silt or clay. The harder minerals such as quartz and feldspar, break up much more slowly, although the removal of the softer minerals loosens up the harder ones and permits rain and small streams to carry them down the slope into larger streams where the finer particles are quickly swept away, thus concentrating the sand into banks and bars.

One, therefore, may rightly expect to form some opinion of the character of parent rocks from the sand that has been produced from them. Granite will form a sand composed of quartz, feldspar, mica, and hornblende. As the sand is carried further from the parent rock, the mica and hornblende and finally the feldspar will be broken up into clay, so that the resulting material will be largely composed of quartz. Sand containing large amounts of the feldspars, such as that making up much of the Altamaha formation in South Georgia, was probably rapidly transported by large, swift streams over comparatively short distances, else the feldspars would have not occured in it. Sandstone and arkose upon disintegrating will leave quartzose and feldspathic sand. Limestone and marble may rarely produce a calcareous sand, but their decay is more usually effected by solution without the production of sand. Shales and slates will, of course break up into silt and clay from which they were formed.

Chemical action.—Decomposition proceeds usually through the solvent action of dilute reagents carried in surface and underground waters, or in atmospheric moisture. Rain, in passing through the atmosphere, acquires sufficient amounts of carbonic acid to render it capable of dissolving practically every type of rock in minute quantities. Organic acids, sulphuric acid, and other solvents produced in water as it passes over vegetation and certain more easily soluble minerals, have a strong solvent effect on the rocks, especially if the water can deeply penetrate them through faces or joints. In this manner, decomposition of the softer and less resistant minerals in a rock mass relieves the harder particles of their support, thus preparing them for removal by water or wind action.

Some rock minerals will take up water or become hydrated, so that their mass is increased, thus exerting a disintegrating force and at the same time making them more susceptible to further decomposition.

Some minerals, containing iron and manganese, have a marked affinity for oxygen, so that they are readily oxidized. This weakens the rock structure, and even highly resistant fragments become loosened and the rock further disintegrates.

As a sand and gravel producer the action of decomposition is indirect. It removes support from the more resistant particles by dissolving or weakening the less resistant, consequently the rock tends to break up, and clay, silt, and the larger grains of sand, and even pebbles, are washed into streams. The sand and gravel, being coarser are not carried away as rapidly as is the clay and silt, but become concentrated in the stream bed and in bars along its course.

The feldspars and hornblende in a granite will be decomposed into clay and iron oxide leaving the quartz, which is only slightly affected by solvents, to accumulate as sand. In more basic rocks, or those containing less quartz or silica, the effect of solution is greater, and the resultant quartz, or ultimate sand, much less.

Schists, gneisses and slates, so common throughout the Piedmont area of Georgia, are decomposed much as are unaltered igneous rocks, except that the process is more rapid since the foliations permit a more thorough impregnation by the dissolving solutions. The proportion of quartz, however, in the resulting sand is usually considerably less than in sand from fresh igneous rocks.

CLASSIFICATION OF SAND

Although commercial sands are frequently divided into bank and stream sands, a further and more detailed classification is necessary and desirable. Sand may be classified, according to its origin, chemical and mineralogical content, grain size and use.

CLASSIFICATION BY ORIGIN[1]

Sand produced by various weathering agencies and remaining where it was produced is known as *residual* sand. Sand having an *aqueous* origin may be found in streams, along sea or lake beaches, in lakes or at the sites of ancient lakes. Sand of *glacial* origin is common in our northern states in poorly stratified, irregular deposits, but it is entirely absent, of course, in Georgia. *Aeolian*, or wind-blown sand, is common along sea coasts, where dunes as much as 100 feet in height have been piled up. These dunes may gradually advance and engulf buildings and whole villages. *Volcanic* sand has been ejected from active volcanoes as lapilli or finer particles. Such sand occurs in parts of the West. Sands of *organic* origin and made up of öolites, rounded concretionary grains produced by microscopic algae, are found on the shores of Great Salt Lake, Utah.[2] Sand formed by concentration of solutions on evaporation has been called *concentration* sand. Examples of this type are found in the salt[3] sand

1 Condit, D. D., Petrographic character of Ohio sands with relation to their origin: Jour. Geology, Vol. 20, pp. 152-163.
2 Rothpletz, Uebur die Bildung der oolithe Botanisches Centralblatt, Vol. 51, p. 267 ,1892. Translation in American Geologist. Vol. 10, p. 279, 1892.
3 Darton, N. H., Zuni salt deposits, U. S. Geol. Survey Bull. 260, p. 565

and gypsum[1] sand deposits of New Mexico. W. H. Sherzer[2] has taken up in detail the classification of sand with respect to its origin.

CLASSIFICATION BY CHEMICAL CONTENT

Chemically, sands differ widely. The most common type probably is *silica* sand whose purity depends on the amount of decomposition the minerals other than quartz have undergone. Most of the Georgia Coastal Plain sands are of this type. Generally a small quantity of iron, less than 2 per cent, will give a yellow or reddish color to a sand. Such sands are called *ferruginous*. *Calcareous* sands, or those containing sufficient calcite to effervesce with acid, occur in the Bermuda Islands and on some of the coral islands off the coast of Florida.

Sands containing organic matter are common in swampy regions. In parts of southeast Georgia the organic matter is in sufficient quantities to afford a brown dye source. Such material is called *sap brown ore.* (See page 373.)

Bituminous or *asphaltic* sands,[3] occur in Alberta, Canada; Kentucky, Missouri, and many other states, and may contain sufficient bituminous matter to permit their use in street paving.

Gold-bearing sands occur in the stream and flood plain deposits of the Appalachian Mountains of Georgia.

CLASSIFICATION BY MINERAL CONTENT

Although *quartz,* due to its durability, is the most common mineral composing sand, practically every type of mineral may be represented among the grains of a sand deposit.

Sands composed entirely of *calcite* occur on the beaches of the Bermudas and other coral islands; and in parts of New Mexico extensive areas occur covered with white sand composed entirely of *gypsum.*[4]

Feldspathic sands contain fragments of the feldspars and are com-

---

1 MacDougal, D. T., Carnegie Institution, Publication No. 90, p. 11, 1908.
2 Criteria for the recognition of the various types of sand grains: Bull. Geol. Soc. America, Vo 21, No. 4, pp. 625-662.
3 Ellis, S. E., Investigation of bituminous sands in northern Alberta: Canada Dept. of Mines, Mines Branch, Sum. Rept. for 1915, pp. 67-76, 1916.
4 Herrick H. N., U. S. Geol. Survey Bull. 223, p. 98.

mon in the sands of the Cretaceous and the so-called Altamaha formation of Georgia. *Kaolinitic* sands are those intermingled with blebs of fine, white kaolin, and are common in the Lower Cretaceous.

Micaceous sand contains scales of mica, either muscovite or biotite, and is common in the Piedmont and some of the Coastal Plain streams. The mica frequently occurs in large flakes. Such sand may produce a crunching noise when rubbed or walked in and hence it has been referred to as "whistling" or "singing" sand.[1] (See page 379.)

Magnetite sands, suitable for iron making occur in Quebec,[2] in New York, on the coast of Lake Champlaine, in Brazil, and in New Zealand. *Glauconite*[3] sands, or green sands, sometimes containing 75 per cent of glauconite, a silicate of iron and potash, are common along the Atlantic Coast as far south as Florida.

Black[4] sands may contain a variety of dark-colored minerals, such as magnetite, ilmenite, zircon, chromite, monazite, and cassiterite, and are a source of the rarer elements such as cerium, thorium, and zirconium. They are particularly abundant in the streams of the Pacific slope. Such sands are also found on the islands bordering the Atlantic Coast of Florida[5] and Georgia.

Chromite[6] sands occur in Maryland and are mined on a small scale for their chrome content.

Monazite sands contain thorium and cerium phosphate and result from the decomposition of monazite-bearing igneous rocks. They are found in small quantities in many of the streams of the Piedmont Plateau and on the islands off the Atlantic Coast of Georgia.

CLASSIFICATION BY GRAIN SIZE

Just as the term sand refers to grains having certain arbitrary upper and lower size limits, just so may sand itself be classified according to the size of its grain. Such a classification is especially desirable for sands used for concrete, mortar and filter purposes.

---

1 King, W. J. H., Travels in the Libyan desert: Geog. Journal, Vol. 39, pp. 133-137.
2 Mackenzie, G. C., Magnetic iron sands of Natashkwan County of Sagnenay, providence o Quebec: Canada Dept, of Mines, Mines Branch, 1912.
3 Mansfield, G. R., General features of the New Jersey glauconite beds: Econ. Geol., Vol. 14 pp. 555-567, 1919.
4 Day, David T. and Richards, R. H., Mineral Resources of the United States: pp. 175-1258, 1905.
5 Liddell, D. M., Eng. & Min. Journal, Vol. 104, p. 4, 1917.
6 Singewald, J. T., Maryland sand chrome ore: Econ. Geol. Vol. 14, pp. 189-199, 1919.

Condra[1] considers three sizes:

Fine sand	0.5 mm. or 0.02 inch in diameter
Medium sand	2.0 mm. or 0.08 inch in diameter
Coarse sand	5.0 mm. or 0.20 inch in diameter

In this report when coarse, medium, or fine sands are mentioned, it is understood that the sizes will be those of the foregoing table.

E. P. Rosa, of the U. S. Bureau of Standards, suggests[2] the following classification for building sands and gravels:

Suggested classifications of building sands

Grade called	Suggested limits
No. 1	Passing an 8-mesh sieve
No. 2.	Passing a 4 mesh sieve
No. 3	Retained on a 4-mesh sieve and passing a ⅜ inch screen
No. 6	⅜ inch to ¾ inch
No. 8	¾ inch to 1½-inch
No. 10	1½-inch to 3 inches

According to Dake[3] the following terms applied to gravel are widely used in Missouri:

Sand	Through ⅛ inch
Torpedo gravel	Through ¼ inch on ⅛ inch; also called torpedo sand
Roofing gravel	Through ¾ inch on ¼ inch
Binder gravel	Through 1½ inch on ¼ inch
Concrete gravel	Through 2½ inch on 1½ inch

CLASSIFICATION BY USES

Probably the most widely used method of sand classification is by their uses. For building purposes we have *concrete* sand and gravel, *brick* sand, *plaster* sand, and *paving* sand. *Glass* sand is one of exceptional freedom from iron. *Foundry* sands consist of a variety of types such as *molding* sand, *core* sand, or *brass* sand, depending on the kind of metal to be cast and the size and quality of the casting. Other uses require the designation of *filter* sand, *loco-*

1 Condra, G. E., Sand and gravel resources and industries of Nebraska: Nebraska Geol. Survey, Vol. 3, pt. 1, p. 29, 1908.

2 Rock products and building materials: Oct. 10, 1917, p. 26.

3 Dake, C. L., The sand and gravel resources of Missouri: Missouri Bureau of Geol. and Mines Vol. XV, p. 7, 1918.

motive sand, *abrasive* sand, and *fire* sand. We also have gravels for *ballast, roofing, road building,* and for use in tube mills. As this report is intended to emphasize the economic features of sand and gravel, the classification by uses will be followed.

COLOR

The color of sand serves as an index of its purity. Pure quartz sand is as white as snow, but only a few tenths of a per cent of iron oxide coating the grains will materially discolor it. Most of the Georgia Coastal Plain sands are a pale yellow, caused by an iron content of from one half to two per cent. Many fine-grained sands of the Piedmont Plateau are speckled, due to black magnetite or ilmenite grains among the lighter quartz grains, and many are dark-colored, due to grains of schist, gneiss, and hornblende. The sands of the Upper Cretaceous occur in brightly colored beds, ranging from white to yellow, pink, red, and even purple. The sands of the Barnwell formation of South Georgia are characteristically bright red, or reddish-brown, as are many of those of the Lower Cretaceous along the Fall Line between Macon and Augusta.

Sands high in organic matter, and which occur in or near swampy regions in Southeast Georgia, are dark brown and even black.

In general, a white or light-colored sand is pure and composed principally of quartz, while dark gray, brown, and black sands are usually lower in quartz and more likely to be impure. A white or light-colored sand, however, does not mean a low clay content. More usually a darker sand contains less clay than a paler sand. In the case of many pure white sands of Lower Cretaceous age associated with the kaolins near the Fall Line, a chemical analysis shows a surprising large iron content. This high percentage is due to ilmenite ($FeTiO_3$) which upon close examination will be revealed in the form of tiny black specks scattered through the pure white sand.

CLEANNESS

The cleanness of a sand is measured by its impurities. What may be impurities in some sands may be necessary for the usefulness of other types, or impurities harmless in certain sands will entirely disqualify others. Iron in quantities as small as 0.05 per cent eliminates sand for use in high-grade optical glass, in fact most sands with more than one per cent of iron are unfit for use in any kind of glass manufacture. For abrasive work, in which only the hardest sand grains are desirable, all grains softer than quartz are considered impurities. Clay or silt may be an impurity in mortar and concrete sands, but necessary in most molding sands. Impurities in molding sand consist rather of coarse particles, the most desirable feature, however, of concrete sands.

CLAY

Clay, by reason of its colloidal properties, will sometimes readily adhere to the quartz sand grains and materially hinder the action of the cement while the mix is hardening. Silt or clay also occurs as separate grains scattered through sand. The amount of clay considered harmful to sand for concrete use depends sometimes on the type of concrete to be made and the personal equation involved. Many concrete users believe that silt or clay up to 15 per cent in lean mixtures is beneficial rather than harmful to the resulting concrete. In rich mixtures, however, 5 per cent is often believed to be too much. This question will be considered in detail under the uses of sand. (Pages 54-56).

Bank sands usually contain the most silt and clay. In recovering stream sands, most of the clay and dirt is carried away by the water draining from the sand, although sometimes a persistent slimy film sticks to the grains. Impurities in sand can usually be reduced by washing, so that a sand otherwise useless may be made available for commerce.

Simple tests will generally determine the cleanness of a sand. Sand that soils the hands when rubbed between them, or one that has not a marked gritty feel, is dirty. A clean sand is usually "sharp"; that is when the grains are rubbed together, and held near the ear, a crackling sound is emitted showing that little clay exists between the grains to deaden the sound of their impact. Another way of quickly finding whether a sand is clean is to drop a quantity of it into a bucket of clear water. If the sand is clean, the water will be clear enough within 2 minutes to enable one to see the sand in the bottom.

For a closer determination of the clay in a sand, put a small amount in a tube or bottle with some water and shake well. After the water has cleared, the clay will form a layer at the top of the sand. The proportion of clay to sand can be readily approximated from the thickness of this layer.

Dake,[1] in determining accurately the percentage of dirt in a sand, stirred a given amount of the dried and weighed sand in a pan with water and then allowed it to settle a given length of time. The water was then poured off and clean water added, and the process repeated until the sand no longer dirtied the water. The clean sand was then dried and weighed, and the percentage of "dirt" determined by the following formula:

$$D = \frac{W - W'}{W} \times 100, \text{ in which}$$

D = percentage of dirt
W = weight of sample before washing
W′ = weight of sample after washing

In this method, particles of wood and other organic matter as well as silt, clay, and iron stains are determined as dirt. The addition of a few drops of a $\frac{1}{100}$ normal solution of sodium hydroxide to a jar containing sand and water will cause the clay in the sand to remain in suspension after the jar is shaken, so that it can be easily decanted.

In testing Georgia sands, the clay percentage was arrived at by shaking up 50 grams of the sand in a half-liter jar, and allowing the material to settle 15 seconds, and then decanting the water and suspended silt and clay. This was repeated until clean water was not clouded when shaken with the sand. The sand was then dried and weighed, and the clay percentage computed in accordance with the preceeding formula.

ORGANIC MATTER

Organic or vegetable matter consists of pieces of coal or lignite, twigs, leaves, and finely divided parts of plants. It may occur as particles scattered through the sand, or as a thin, loamy film or coating on the sand grain which is frequently imperceptible. Organic matter, even in small amounts, is usually undesirable and even harmful in sand used for most purposes, particularly in sand for use in construction work. (See page 56).

In the field organic matter can be detected by taking double handsful of sand from the bank or pile and letting it run through the hands.

1 Op. cit., p. 9.

As this is done the hands should be held with the palms facing each other and about an inch apart, with the thumbs up. To hasten the experiment the hands may be moved backward and forward at the same time. If a dark shining material collects between the fingers it indicates harmful organic matter[1]. The mere fact that a sand is dark-colored is no gage of its organic content. The color may be due to dark mineral grains.

Laboratory tests of organic matter can be made by the loss-on-ignition method in which the sand is first thoroughly washed. After drying and weighing the silt and clay, which were washed out, they are ignited and weighed again. The difference in weight represents not only the organic matter, but the water of crystallization and hydration, and the carbon dioxide. In some limestone sands the loss on ingition, due to carbon dioxide, may exceed 10 per cent, although no organic matter occurs in the sand.

Abrams and Harder[2] have recently divised a colorimetric test for detecting organic impurities in sands which is believed to be reliable. For approximate tests, a 12-ounce graduated prescription bottle is filled to the 4½-ounce mark with sand. To this is added a 3 per cent solution of sodium hydroxide until the volume of the sand and solution, after shaking, amounts to 7 ounces. This is then shaken thoroughly and allowed to stand over night. If the liquid in the bottle, after settling, is colorless, or has a slight yellow color, the sand is satisfactory as far as organic impurities are concerned. If, however, a dark-colored solution is obtained, ranging from dark red to black, the sand should be rejected or used only after mortar-strength tests have been made. A chart[3], showing in colored plates 5 different intensities of the reaction in this test, has been prepared and may be obtained at the Atlanta office of the Portland Cement Association. Comparision of the color obtained in the field tests with the plates will show whether the amount of organic matter is injurious. The proportion of clay or silt in a sand can be determined at the same time by noting the thickness of the silt layer above the sand.

For laboratory work the method recommended is as follows:

---

1 Thompson, S. E., Am. Soc. Civil Eng. Trans., Vol. 51, p. 252, 1911.

2 Abrams, D. A. & Harder, O. E., Colorimetric test for organic impurities in sand: Circular No. 1, Struc. Mat. Res. Lab., Lewis Inst., Chicago, 1917; also in Proc. Am. Soc. for Test. Materials Vol. 17, pt. 1, pp. 327-333, 1917.

3 Concrete Highway Magazine, February, 1918.

"To[1] a 200-gram sample of dry sand add 100 cc. of a 3 per cent solution of sodium hydroxide (NaOH) and digest at ordinary temperature, with occasional stirring, for 24 hours. Filter this solution through a good grade of filter paper; refilter if necessary. The filtrate **must** be clear. Place 10 cc. of the **clear** filtrate in a 50 cc. Nessler cylinder and dilute to 50 cc. with distilled water. Shake thoroughly and let stand until all foam and bubbles disappear. Determine the color value of this cylinder by comparing it with cylinders containing standard solutions of alkaline sodium tannate. Compare the colors by looking through the full depth of the solution with the cylinders held toward a good natural light.

Standard Tannic Acid Solution for Color Comparison.—The preparation of the standard tannic acid solution for comparing the color of the filtrate should be begun at the same time as the treatment of the sand. Add 10 cc. of a 2 per cent solution of tannic acid in 10 per cent alcohol to 90 cc. of a 3 per cent solution of sodium hydroxide. The sodium hydroxide combines with the tannic acid to form sodium tannate. Let the solution stand 24 hours at room temperature. Place 1, 2, 3, 4, 5, 6, 7, 8, 9 and 10 cc. respectively, of this solution in 50 cc. Nessler cylinders and dilute to the mark with distilled water. The amounts of tannic acid in the different cylinders will then be as shown in the following table:

Alkaline Sodium Tannate in each cylinder-cc.	1	2	3	4	5	6	7	8	9	10
Tannic acid in each cylinder-millgrams	2	4	6	8	10	12	14	16	18	20
Color value in parts of tannic acid per million of sand by weight	100	200	300	400	500	600	700	800	900	1000

It is desirable to have good sunlight for comparing the colors; if sunlight is not available, the amount of tannic acid in each of the cylinders containing the standard solutions may be decreased by one-half and the other values in the table modified accordingly.

In case the solution obtained by digesting the sand with the sodium hydroxide is very dark, use less than 10 cc. for the comparison and make the necessary modifications in the calculation of the color values. With very light-colored solutions use more than 10 cc. of the filtrate for the comparisons. The depth of color of the solution decreases on standing, and for that reason the solution should be made up fresh for each day's work.

Method of Calculation—An example will make clear the method of calculating the color value of a sand. Suppose that 10 cc. of clear filtrate obtained by digesting the sand with 100 cc. of a 3 per cent solution of sodium hydroxide when diluted to 50 cc. corresponds in color to the Nessler cylinder containing 12 millgrams of tannic acid, or 6 cc. of the alkaline tannate solution. The sand will then have a color value of 600. The 10 cc. of the filtrate placed in the Nessler cylinder is $\frac{1}{10}$ of the 100 cc. of 3 per cent sodium hydroxide solution which was added to the sand, and the sample of sand (200 grams) is $\frac{1}{5}$ of a kilogram; therefore, the milligrams of tannic acid per kilogram of the sand, by weight, are 12x10x5=600; or the tannic acid equivalent when expressed in parts per million of the sand, by weight, is 600.

It[2] is impracticable to give exact values for the relation between the color value of a sand and the strength of mortars made from the same sand. However, the tests made thus far show this relation to be about as follows:

1 Op. cit., pp. 3-4

2 Op. cit., p. 5.

Color values of sand	Plate number[1]	Reduction in compressive strength of 1-3 mortar per cent
250	2	10–20
500	3	15–30
1,000	3–4	20–40
2,000	4	25–50
3,000	4–5	30–60

1. Plates may be obtained from Atlanta office of Portland Cement Association.

In the testing of Georgia sands, the color value tests indicating the comparative amounts of organic matter in the sand, were made in the Survey laboratory by Dr. Edgar Everhart, and the results have been tabulated with the other tests made on the sands.

MINERAL AND ROCK COMPOSITION

The mineralogical composition of a sand depends entirely on the mineral character of the component grains. As previously stated (pages 5-6) we may have quartz, calcite, gypsum, feldspar, mica, magnetite, and many other types of sand. Since quartz is so predominate in most sands, the examination from a mineral standpoint is not always necessary. Many sands, however, particularly those in the streams of the Piedmont area in Georgia, contain a considerable proportion of feldspar, hornblende, and mica, which may seriously affect the value of mortar or concrete made from them. From a casual examination, harmful amounts of such minerals can generally be detected. A more detailed microscopic examination, however, is sometimes necessary before deciding which of several sands is best suited for a particular purpose.

SAND-PRODUCING MINERALS

Quartz. (SiO_2). Most sands are composed almost entirely of quartz. It generally occurs as irregular angular grains having the appearance of broken glass, although frequently the edges and corners are rounded, but the faces are generally rough and pitted. Quartz is hard and easily scratches glass. It is usually colorless or gray, but may be stained yellow to red with iron oxide or clay.

Feldspar ($KAlSi_3O_8$).—Feldspar is a group term applied to several minerals resembling each other. They form angular grains, but differ from quartz in having smooth, tabular faces, or sides. Feldspar may be white, pink, or yellow. It is softer than quartz, and lacks the glassy appearance of that mineral. Feldspar is common in the Piedmont stream sands and in the mottled grits of the central Coastal Plain.

Mica ($H_2K\ Al_3\ (SiO_4)_3$)—Mica is easily recognized by its flat, shining, scaly flakes. In sand, these flakes may occur smaller than a pinhead or as much as an inch across. It occurs as the white variety, muscovite, ($H_2K\ Al_3(SiO_4)_3$ and as the black variety, biotite, $(H,K)_2$ $(MgFe)_2\ Al_2\ (SiO_4)_3$, and is found in most Georgia sands, but it is particularly common in some of the Piedmont streams. In amounts over 2½ per cent it is considered harmful to concrete sand.

Hornblende ($CaMg_3\ (SiO_4)_3$)—Hornblende is usually black or dark green, and forms irregular, angular grains, generally prismatic in form. It is about as hard as feldspar and scratches glass with difficulty. Due to its ready decomposition it is not found far from the igneous rocks in which it was formed. It occurs in small quantities in most of the Piedmont sands.

Calcite ($CaCO_3$).—Calcite is generally white and usually forms grains with sharp, rhombic angles. It is easily scratched with a knife. Calcite is rarely found in Georgia sands.

Limonite ($2\ Fe_3O_3.\ 3H_2O$).—Limonite is a fairly soft, yellow to brown, lusterless oxide of iron, and is a principal impurity in glass sands, although very valuable as a binder in road gravel.

Magnetite (Fe_3O_4).—Magnetite is a heavy, black mineral, capable of being attracted by a magnet. Its grains are usually small and irregular. It may be seen arranged in layers or streaks in sand, or standing out as black specks. With it, ilmenite ($FeTiO_3$), which is similar in appearance, but not as magnetic, occurs in considerable amounts in the sand on the islands off the Atlantic coast. Numerous other minerals, such as brookite, rutile, chromite, and glauconite, are dark colored and can be detected in these sands with the aid of the microscope or heavy solutions.

In addition to the foregoing minerals, garnet, a hard, red or brown mineral of irregular, angular grains, is sometimes found in sand. Monazite, a yellowish to reddish, hard, sharp-cornered mineral is found in stream sand at The Glades in Hall County and on the coastal islands.

SAND-PRODUCING ROCKS

Since Georgia sands and gravels in many places contain fragments of rocks, which are merely large aggregates of one or more minerals, a brief description of the commoner types is given to serve in their identification.

SEDIMENTARY ROCKS

The sedimentary rocks are those formed under water by the accumulation of sediment carried and deposited by the water and later hardened by pressure and cementation. They are found in the Paleozoic area of northwest Georgia and at a few places in the Coastal Plain.

Sandstone.—Sand that has become indurated through pressure, or the cementing action of percolating solutions, is known as sandstone.

Quartzite.—Sandstone that has been subjected to pressure, heat, or solvent action, until the outlines of the original sand grains are almost obliterated, causing the rock to crack across the individual grains, rather than around them, is called quartzite. It forms a large percentage of the pebbles in Georgia gravels, particularly those of the Coastal Plain and Fall Line regions, and is very resistant.

Conglomerate.—Gravel that has been cemented into a hard rock by water containing silica, carbonates, or other substances in solution, is called conglomerate.

Limestone.—Limestone, or its crystalline equivalent, marble, is usually gray or blue. It may be pink, green, or black. It is soft enough to be scratched easily with a knife, and effervesces with acid or strong vinegar. The stream gravels of the Paleozoic area have a considerable amount of limestone pebbles.

Shale.—Shale is hardened clay or mud. It is of various colors, although usually gray or brown, and generally forms thin, flat, soft pebbles which occur in the stream gravels of the Appalachian Valley province.

CRYSTALLINE ROCKS

The crystalline rocks are those formed by the cooling, on or beneath the earth's surface, of lava that has been forced up from the earth's nterior; or by the metamorphosis, by heat or pressure, of sedimentary rocks. They are found in the Piedmont Plateau and in the Appalachian Mountains of North Georgia.

Granite.—The most common igneous rock is granite. It is gray, or pink, and composed principally of quartz, feldspar, and mica, which form a closely interlocked crystalline texture.

Diabase.—Diabase is a hard, dark, fine-grained, heavy rock, which in Georgia generally occurs in long, thin formations known as trap dikes. Pebbles of diabase occur rarely in Georgia gravels.

Gneiss.—Gneiss is composed of thin, paralled bands of light and dark minerals and results from the metamorphosis of igneous and sedimentary rocks. Pebbles derived from it are not so hard or resistant as those from granite or basalt.

Schist.—Schist is perhaps the most common crystalline rock in Georgia. It is a thinly laminated, flaky rock. Fragments of it are common in the Piedmont sands and gravels, but they readily tend to break up into smaller fragments and for that reason are an undesirable constituent.

Slate.—Slate is metamorphosed shale. It occurs in the stream gravels in Polk and Bartow counties as thin, flat, hard fragments.

MINERALOGICAL EXAMINATION OF SAND

To determine roughly the mineral and rock content of a sand, some of it can be spread out on a sheet of paper and the various mineral types sorted with a small, blunt stick into separate piles. The percentage proportion of each mineral, or rock, is then roughly estimated. Another portion of the sand is then examined under a microscope to discover any minerals not seen in the rough division and to note the shape of the sand grains and whether they are coated with clay, iron oxide, or other materials.

Sands containing a fairly large amount of the heavier minerals, such as those found on the sea coast of Georgia, can be panned. A shallow, circular pan, about 24 inches across, is used for this purpose. The sand is gently agitated under water with a slight rotary motion and a jerking throw. The heavier minerals are concentrated at the bottom of the sand and the quartz can be easily removed. The process is repeated until very few light grains remain in the pan.

Tomlinson,[1] in testing Wisconsin concrete sands, used a detailed method in which the exact proportion of each of a number of mineral groups was obtained. The sand to be examined was first sized by screening through 10–, 20–, 40–, and 100-mesh sieves. The sand retained on the 20-mesh sieve was then immersed in Thoulet's solution of potassium mercuric iodide, the density of which can be changed by increasing or decreasing the water A funnel whose spout is fitted with a stop-cock is best suited for this treatment. The heavy grains will collect in the lower part of the spout, above the stop-cock, and can be easily removed by opening the cock. The sand retained on the 20-, 40-, and 100-mesh sieve was treated in the same manner. The sand that remained on the 10-mesh sieve was sorted into the component minerals by hand.

Since two or more minerals or rocks may have the same density, it is necessary to examine each of the divisions made by use of the heavy solution. This was done with a microscope or large hand lens. The grains to be examined were spread out evenly upon a glass plate overlying a ruled counting sheet. The number of grains of any particular mineral occurring in one or more squares, depending on the size of the sample, was counted and multiplied by the total number of squares occupied by the sample.

The results of the examination were tabulated under the following groups: Igneous rocks, shale group, quartz group (includes quartz, chert and quartzite), dolomite group (calcareous sediments), feldspar, and heavy minerals. Bromoform, having a density of 2.84, and methyl iodide, density of 3.3, have also been used in separating the heavy minerals.

CHEMICAL COMPOSITION

Aside from a scientific interest, there is little practical value in a chemical analysis of sands except for those used in glass making or for refractory purposes. The iron content as Fe_2O_3, the alumina as Al_2O_3, and the silica as SiO_2 are the most important determinations in glass sands. Magnesia (MgO), titania (TiO_2), and organic matter are also usually determined. In refractory sands the silica, and fluxing materials such as iron, soda, potash, magnesia, and lime, are generally found. Sometimes a chemical analysis of filter sands

1 Tomlinson, C. W., Method of making mineralogical analysis of sand: Am. Inst. Min. Eng. Trans., Vol. 52, pp. 852-862, 1916.

is made to determine the silica, iron, lime, magnesia, alkalies, and organic matter. In concrete sands, it is necessary to know only the organic content of the sand. In sands used for ores, such as those containing magnetite, chrome, monazite, zircon, and other rarer materials, the constituent elements of these minerals are determined in addition to the commoner elements. In sap-brown the amount of material soluble in alkalie is usually determined as a guide to the dye-making content of the substance.

In sand the silica is largely in the form of quartz with smaller amounts in silicate grains such as feldspar, hornblende, mica, and other minerals. The iron generally occurs as the oxide, limonite, or more rarely in magnetite and ilmenite, and in smaller quantities in hornblende and biotite. Clay, kaolinite, and feldspar generally account for the alumina in the sand. Lime and magnesia come from grains of limestone, from calcite or dolomite occurring as cementing material, or from shell particles. Grains of feldspar, hornblende, and olivine supply lime and magnesia in smaller amounts. The alkalies, soda and potash, are usually derived from the feldspars and micas. Titanium may come from ilmenite and rutile. Water (H_2O) and carbon dioxide (CO_2), found in a detailed analysis, or simply as volatile matter, usually come from the kaolinite, and from the lime or magnesia occurring either in limestone or precipitated in small quantities in the sand as carbonates.

A number of analyses of all types of Georgia sands have been made both to determine their value in glass-making and for their scientific value.

PHYSICAL CHARACTER OF SAND GRAINS

The size, shape, and strength of the individual sand grains or gravel pebbles are important factors in determining the desirability of sand and gravel for every use.

SIZE OF GRAIN

The usual method of determining the grain size of sand is by screening or sieving. The size of the grain may also be determined by the aspirator method, in which the time required for air to pass through a mass of sand is used to determine the average size of the grain composing the mass. Division of sand into its different grain sizes is also made by elutriation. The actual size of sand grains can be directly measured by the use of a micrometer scale in a microscope.

GRAIN SIZE BY SCREENING

The size of the particles composing sand is usually determined by passing the sand through a series of sieves having meshes of decreasing size. Since the grading of a sand, or the proportions of grains of each size, is known to greatly influence the value of a sand for either concrete, glass, or molding purposes, the necessity of a reliable granulometric or mechanical analysis is at once apparent.

In making the mechanical analysis several systems of screens are in use. That most generally employed is the so-called standard screen system, whose mesh increases by ten to the inch from one screen to the next smaller. A more logical system, however, has been devised in which a constant ratio, $\sqrt{2}$ or 1.414, exists between the diameters of the apertures of the screens. The area of the mesh opening in each screen in then just twice that of the next smaller sized screen.

It was found that the latter of these two systems gave the most satisfactory results since it divides the material in much better proportion. In the old system, too few a number of sieves are used where the most grains of equal size occur, and too many are used where the least grains of equal size are found.

To illustrate this, in one hundred and five sands from Nebraska, Missouri, Pennsylvania, and New York, an average of 61 per cent of each sand remained on a 50-mesh screen, 23 per cent passed the 50-mesh, and 16 per cent remained on the 10-mesh. In the old system of screens only 5 sieves, (50–, 40–, 30–, 20–, and 10-mesh), are used to apportion this 61 per cent into its various grain sizes, and 7 sieves, (60–, 70–, 80–, 90–, 100–, and 200-mesh), are used to divide up the 23 per cent. In the new system 6 screens (10–, 14–, 20–, 28–, 35–, and 48-mesh) would be used to divide up the 61 per cent, and 4 screens (65–, 100–, 150–, and 200-mesh) to divide the 23 per cent. The average of 16 per cent that remains on the 10-mesh sieve can be divided by four screens or by three (4–,6–, 8–mesh) as was done in testing Georgia sands for this report.

It is thus seen that for most sands a screen system, having the areas of the apertures of the same proportionate difference between each screen, is the most desirable. By excluding every other screen in making mechanical analysis by this system, the material can be divided into parts whose average diameters are just half that of the next coarser screen. This system is used in several leading concrete testing laboratories in the United States, including that of the Bureau of Standards, the Bureau of Public Roads, Lewis Institute, and is also used in the work of the Canada Department of Mines. Objection to the use of this system might be made on the ground that sand users in general are not familiar with the significance of several of the screen sizes when seen in an analysis. This is especially true of asphalt sands since specifications for such sands are universally made in terms of the standard system. Either system, however, can be readily interpreted in terms of the other, if the results are plotted to scale on coordinate or chart paper.

Table of screen mesh sizes used in testing Georgia sands

Mesh	Diameter of wire in inches	Diameter of opening	
		inches	mm.
4	.065	.185	4.699
6	.036	.131	3.327
8	.032	.093	2.362
10	.035	.065	1.651
14	.025	.046	1.168
20	.0172	.0328	.833
28	.0125	.0232	.589
35	.0122	.0164	.417
48	.0092	.0116	.295
65	.0072	.0082	.208
100	.0041	.0058	.147
150	.0026	.0041	.104
200	.0021	.0029	.074

The following procedure was followed in testing Georgia sands: the entire field sample weighing from 5 to 12 pounds was halved with a sampling shovel until about 200 grams remained. This was thoroughly dried at 100°C. to prevent cohesion of the grains by moisture. A 100-gram sample was then selected and placed in the upper of 6 sieves arranged in order of their size: 4–,6–,8–, 10–,14–, and 20-mesh. This nest of sieves was shaken for about five minutes, and the amounts remaining on each sieve weighed separately, after first shaking each sieve over a paper to insure complete separation of fines. The sand passing the 20-mesh sieve, and caught in the pan, was placed in the

28-mesh sieve, or the upper of the 7 remaining sieves, and after 5 minutes shaking, the separates were weighed.

Two samples of the same sand were subjected to this method and the following constant results obtained:

Table giving percentage of sample retained on each sieve

Sample	Mesh Sizes											
	10	14	20	28	35	48	65	100	150	200	200	Total
T-60a	.5	1.9	5.8	13.1	22.8	23.5	17.9	9.9	2.9	1.2	.3	99.7
T-60b	.4	1.8	5.6	12.9	22.6	23.1	18.5	9.5	2.7	1.4	.5	99.0

Since it is practically impossible to avoid loss in screening, the percentages listed in the tables in this report were recomputed to a 100 per cent basis, thus the results from T-60b in the foregoing table with the 1 per cent loss proportionately distributed over the entire number of separates would be as follows:

Table showing uncorrected and corrected percentage of sample retained on each sieve

Sample	Mesh Sizes											
	10	14	20	28	35	48	65	100	150	200	200	Total
T-60b	.4	1.8	5.6	12.9	22.6	23.1	18.5	9.5	2.7	1.4	.5	99.0
T-60b	.4	1.8	5.7	13.0	22.8	23.4	18.7	9.6	2.7	1.4	.5	100.0

This necessary error might also have been allowed for by adding it to the percentage of the sample under 100 mesh, or by starting with a gram more than the required 100 grams.

For a closer determination of the fines, sifting under water is desirable, since clay particles that might adhere to larger grains are thus loosened and go with the smaller sizes. In very exact work the sand samples are sent from the field in air-tight containers and weighed with the original pit moisture. They are then dried and the percentages of the various separates based on this weight.

In testing sandstones it is necessary to crush the rock. Care should be taken so that the crushing does not break up individual grains and that it does not leave two or more grains cemented together. No Georgia sandstones were submitted to mechanical analyses.

In the case of a few sands dredged from river beds by centrifugal pumps most of the fines have been washed out with the water. Mechanical analyses of such sands are therefore not representative of the true character of the natural sand, but do indicate the grading of the commercial product.

In place of hand sifting, the sieves may be agitated automatically by a small motor, or geared to a crank which is turned by hand. Many of the larger sand-testing laboratories have adopted mechanical shakers of some sort, not only to reduce the manual labor but to obtain more constant results with less loss of the original sample. Forrest[1] gives the following comparisons between results obtained from the same samples by hand and by mechanical sifting. The figures represent the sum of the percentages retained on each screen and passing the finest.

Comparative results of hand and mechanical sifting

Total percentage from 50 gram sample of sand				Total percentage of 1000 gram sample of concrete aggregate	
Hand sifted		Mechanically sifted		Hand sifted	Mechanically sifted
99.4	99.2	99.7	99.8	98.4	99.5

Gravel.—For the complete mechanical analysis of gravel, screens of the following sizes may be used: ¼, ⅜, ½, ¾, 1, 1½, 2, 2½, and 3 inches. The use of all these sizes is only recommended where the gravel is to be used in very large and important work, usually the ¼-, ½-, 1-, and 3-inch screens are sufficient.

In this report screens of ¼-, ¾-, and 1¼-inch mesh were used. In the gravels tested the sand was first screened out, and after its proportion of the whole sample was found, a granulometric analysis of both the sand and gravel was made.

For finding the relative amounts of sand and gravel in small stream deposits, which may be utilized for local concrete construction and building, Clifford Older[2] has described a system requiring the use of

1 Forrest, C. N., New device for the analysis of concrete aggregates: Am. Soc. for Test. Mat. Proc., Vol. 6, pp. 458-461, 1906.
2 Eng. News, Vol. 72, pp. 1204-1205, 1914.

portable sieves and containers of simple construction. The apparatus consists of a testing can, 4 inches in diameter and 10 inches deep; three screens of 10 mesh, ¼–, and ½–inch mesh, which fit into the can; a 200 cc. graduate, 1 inch in diameter; and a 10-inch scale divided into inches and tenths of inches.

To test a creek deposit the can is filled level full with gravel and the sand separated out by the ¼–inch sieve. The sand is poured back into the can and its proportion to gravel measured by the scale, the zero mark of the scale being down. The following formulae are used to determine the amount of cement to be added to the unscreened gravel to produce a concrete having a required sand-cement ratio

$$A = \frac{28.4x}{a}; \qquad B = \frac{0.95\,a}{x}; \qquad C = bx - y$$

in which,

A = Bags cement required per cubic yard gravel
B = Cubic feet of gravel to be used with each bag of cement
C = Amount of stone to be added to a unit volume of gravel in order a minimum amount of cement be used
x = Ratio of volume of separated sand to unscreened gravel.
y = Ratio of volume of separated stone to unscreened gravel; (x-y) should equal about 1.10 to 1.25 in well-graded gravel.
a = Required ratio of sand to cement
b = Maximum ratio of stone to sand

GRAIN SIZE BY OTHER METHODS

Screen methods of mechanical analysis apply to most sand for concrete and glass uses, since such sands are relatively coarse. Molding sands, however, due to the large admixture of clay required to produce a sand capable of retaining shapes, require, in addition to a screen analysis, some other method of separating the finer silt and clay grains into their different sizes. This large clay content also causes the sand to cake or "ball up" so that accurate separation by screening can only be effected by screening in water and by placing light washers or steel balls on the sieve with the sand. The washers or balls, rolling about on the agitated screen, break up the lumps into separate grains.

In determining the amount of silt and clay in a molding sand Ries and Rosen[1] used a method applicable to all kinds of sands. A 50-gram sample of the sand was first thoroughly shaken with water in a mechanical shaker for a half hour. The sample was then screened

1 Ries, Heinrich, and Rosen, J. A., Report on foundry sands: Michigan Geol. Survey, 9th Ann. Rept., p. 46, 1908.

through a set of 20–,40–, 60–, 80, and 100-mesh sieves, and all that passes the 100-mesh sieve was allowed to settle in a jar for 45 seconds. The suspended matter, called clay, (passing $\frac{1}{250}$ mesh) was decanted, dried and weighed, and the sediment, called silt ($\frac{1}{250}$– $\frac{1}{250}$ mesh), was also dried and weighed and the proportion of each in the original sample determined.

In the elutriation method, a constant amount of water is passed through flasks of increasing size. The current is swiftest in the smallest flask, and the largest grains can settle out in this flask only; the rest will be forced over into the next larger flask with the water, where the current is decreased, permitting settling of a group of smaller grains. The process is continued until as complete a division of the material as is desired, is effected.

The time necessary for a known volume of air under a known pressure to pass through a tube of sand is used to complete the average size of the grains in a sand or clay. This method is particularly applicable to molding sands and soils and is called the aspirator method. It was devised by Prof. King[1] and has been used by Rosen[2] in determining the average grain size of Michigan molding sands.

In testing these sands the sample is first dried and pulverized and then passed through a 1-mm. sieve (20 mesh). The sand is then put into a soil tube, which is lightly tapped, and more sand is added until the tube is full. Air under known pressure is aspirated through the tube and the length of time necessary for the passage of one or more liters is found. This data is used in a formula to determine the average size of the grain particles in the sand. Objection to this method is made on the ground that as the first part of the air passes through the sand, channels are set up in the sand which allow the more rapid progress of the rest of the air. The character of these channels is likely to differ in different sands, so that the method is not entirely comparative.

A similar method, involving the length of time elapsing between the entrance of an inflammable gas at the lower end of a sand-filled tube and its exit at the upper end, has been used by L. H. Cole[3] in testing Canadian molding sands. A small tube about 6 inches long and 1 inch in diameter is fitted with 60– and 12-inch wire gauzes at

1 King, F. H., Michigan Acad. Sci., 2d Ann. Rep., 1894.
2 Ries, Heinrich and Rosen, J. A. op. cit., pp. 53-56.
3 Canada Dept. of Mines Branch, Bull. 21 or Sum. Rept. for 1916.

the bottom and attached to a gas pipe having a manometer so that the pressure of the gas can be kept constant. Sand is added to the tube one inch at a time and tamped as it is added until the tube is full. Gas is then passed through the sand and a device is arranged to ignite it, as soon as it begins to escape at the top. The time required for the gas to pass through the sand is determined with a stop watch. For No. 0 Albany molding sand about 22 seconds are needed and $4\frac{2}{5}$ seconds for No. 3. This method is not open to the same objection as the previous method, but the character of the gas and the pressure must be closely watched in order to be certain of comparative results.

GRAPHIC REPRESENTATIONS OF GRANULOMETRIC COMPOSITION

The significance of a granulometric analysis of a sand when presented in the usual tabular form is difficult to comprehend unless one is experienced in examining such analyses. By graphically representing these results either by curves, radiating lines, or by some other system, their meaning can be quickly and effectively grasped. Granulometric analyses, arrived at by using one set of screen sizes, can also be converted into terms of any other size or set of sizes by plotting the original data graphically on chart or co-ordinate paper.

The usual method is that shown in Fig. 1 and consists in dividing the ordinate, or horizontal base line, into proportionate parts to represent the size of the sand grains in terms of millimeters, inches, and sieve sizes; and in dividing the abscissa, or vertical line, to represent the percentages of grain sizes either passing, or retained on, the different screens. Within the space formed by these lines the percentage of each size to the whole sample is marked by a dot and these dots later connected by a smooth curve. By comparing curves of this kind with curves of ideal sands, or with curves representing certain features of excessive coarseness or fineness, a close idea of the granulometric character of the sand in question is obtained. For comparison and to save space, a number of sands can readily be plotted together.

The graphical method used by Ries[1] in figuring Wisconsin and Michigan molding sands is excellent. On the four lines *a, b, c, d* (Fig. 2), equal distances are laid off to represent 100 per cent. On *a* the clay percentage is laid off, on *b* the percentage retained on 100-

---

[1] Ries, Heinrich and Gallup, F. L., Wisconsin Geol. & Nat. Hist. Survey, Bull. 15, p. 207, 1906.

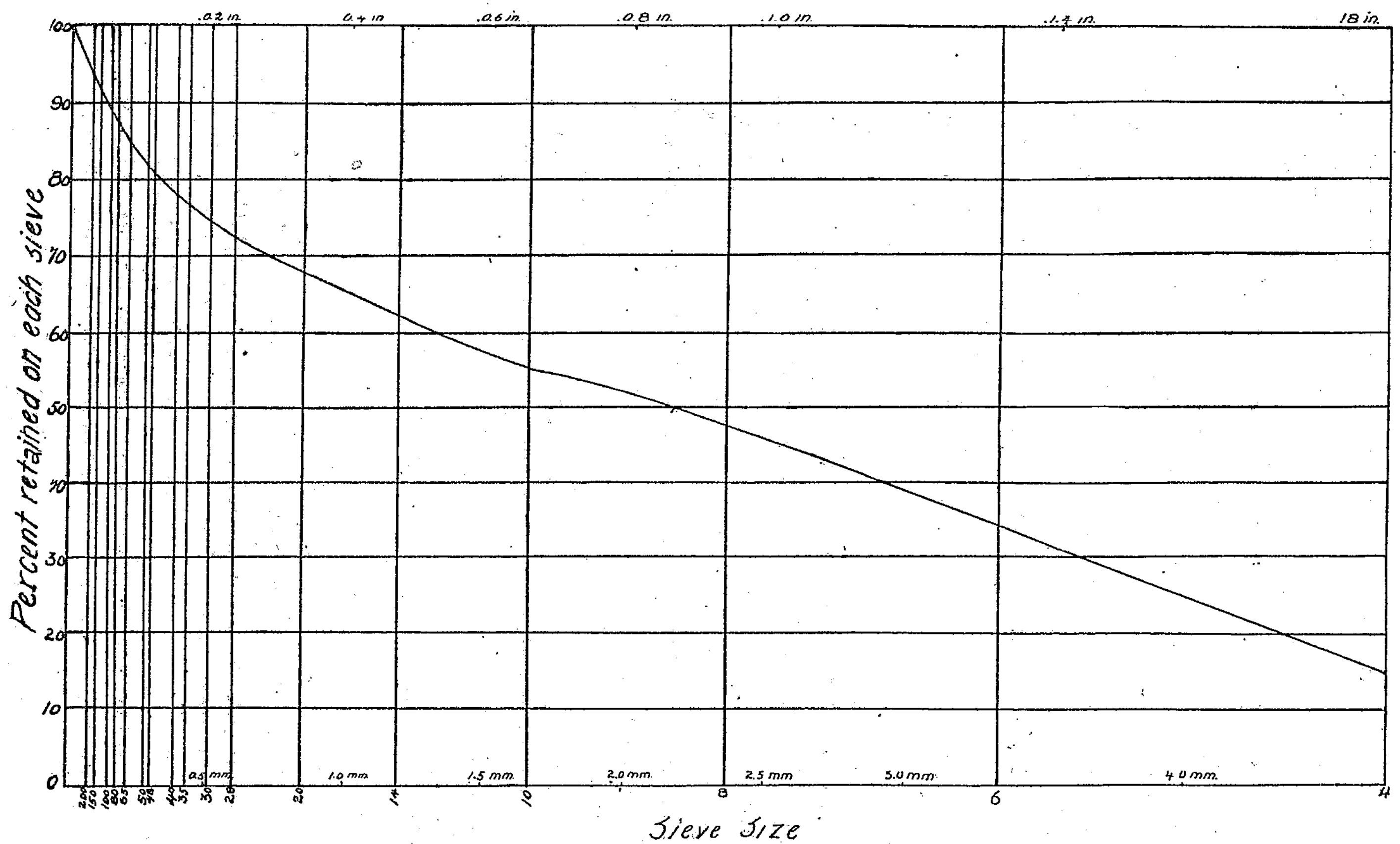
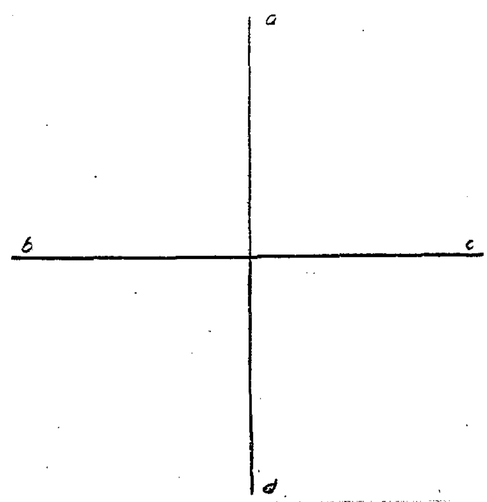
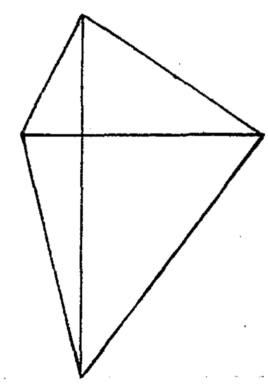


Fig. 1.—Curve of uniformily graded sand

mesh, on *c* the percentage obtained by settling, and on *d* the combined percentages of sand retained on the 20–, 40–, 60–, and 80-mesh sieves. The points on the four lines are then connected by straight lines and the figure produced shows at a glance the texture of the sand (Fig 3). For coarser building and glass sands each line may be made to represent some other arbitrary size or sizes best suited to display the texture of the particular type of sand.





Figs. 2 & 3.—Diagrams showing methods of graphically illustrating the mechanical analysis of a sand.

NUMERICAL REPRESENTATIONS OF GRANULOMETRIC COMPOSITION

To provide rapid means of comparing the granulometric composition of sand and gravel, and for comparing the value of sand and gravel for concrete and filter purposes, a number of methods have been devised to represent by a single number the coarseness and fineness of a sand, its uniformity, or the average size of all the component grains. Some have condemned such methods because of their inadequate expression of the true character of the sand, or on account of complexities which are not readily understood by those for whose help the methods were devised. Nevertheless, some of these means are undoubtedly of value and a few of them will be outlined.

EFFECTIVE SIZE

The term effective size was introduced by Hazen[1] and is defined

[1] Hazen, Allen, Massachusetts State Board of Health Rept., 1892, pp. 549, 550.

by him as a size "such that ten per cent is of smaller grains, and 90 per cent is of larger grains than the size given." In other words, if 10 per cent of the sand in a given sample passes a 1-millimeter screen, and 90 per cent is retained on the screen, then the effective size of the sample would be 1. The effective size of a sand can be readily found by plotting the mechanical analysis of the sand and noting the size in millimeters than which 10 per cent of the material is finer. To compute the effective size without the curve, the mechanical analysis should be arranged to show the percentages retained on each screen. The percentages between which 90 per cent lies should then be noted as well as the mesh opening in millimeters on which these percentages are retained. The proportionate differences between 90 per cent and the adjoining percentages are found and used to determine a mesh size having a similar position between the two mesh sizes on which the percentages were retained. This mesh size represents the effective size of the sand.

The effective size is used in computing the uniformity coefficient of a sand, and it serves as an index of the coarseness of a sand. It has been used principally in describing filter sands and to a smaller extent for building sands. Both the effective size and the uniformity coefficient are of more value when considered together in determining the coarseness or uniformity of a sand.

UNIFORMITY COEFFICIENT

The uniformity coefficient was also introduced by Hazen[1] to give expression to the uniformity of the grains composing a sand or soil. This figure is determined by making a mechanical analysis of the sand and then finding the size of grain of which 60 per cent of the grains is smaller and 40 per cent larger, either by plotting the curve or by interpolation, as was described in finding the effective size. This size is then divided by the effective size of the sample, and the uniformity coefficient is obtained.

Thus, if 60 per cent of a sample is finer than 0.45 millimeter and 10 per cent finer than 0.30 millimeter (effective size), the uniformity coefficient is $\frac{0.45}{0.30}$ or 1.5. In other words one half of the sand grains lie between 0.30 millimeter and 0.45 millimeter. In another sand, if 60 per cent of its grains were finer than 0.3 millimeter, and the effec-

1 Op. cit., p. 550.

tive size was 0.2 millimeter, the same result 1.5 would be obtained, showing that the uniformity coefficient in itself is not a gage of a sand's coarseness, but merely a relative expression of uniformity. As this figure increases it indicates a greater range in size of 50 per cent of the sand grains, which is believed desirable for mortar and concrete sands. Taylor and Thompson[1] consider a sand, whose coefficient exceeds 4.5, to be a good concrete sand and of two sands the one having the largest coefficient is likely to be the best. Should it drop nearly to 1, it would indicate that almost half of the sand grains was of the same size, a condition particularly desirable in filter sands where uniformity is a necessary quality. The use of the term is largely restricted to the description of filter sands. (Page 90).

AVERAGE FINENESS

It is sometimes desirable, especially in molding sands, to express by a single figure the average grain size, or average fineness, of a sand in terms that will be comparable when different methods of mechanical analyses are used.

The system described in the Textbook of Molding Sand issued by the International Correspondence Schools at Scranton, Pa., is as follows: A 100-gram sample is sifted for one minute on 20–, 40–, 60–80–, and 100-mesh screens separately. Any loss is added to the 60-mesh and all sand coarser than the 20-mesh is said to be of 1 mesh. The weight of sand passing each sieve and retained on the next is multiplied by the mesh of the retaining sieve and the total divided by 100. The following example illustrates the method:

Mesh	Weight in grams passing first screen and retained on next	Product of mesh size by percentage on that mesh
1	2.0	2
10	8.0	80
20	12.0	240
40	20.0	800
60	30.0	1800 (60 = 1% loss)
80	25.0	2000
100	2.0	200
	99.0 (1% loss)	5182

1 Taylor, F. W. and Thompson, S. E., Concrete, plain and reinforced: 2nd. ed., p. 182, 1911.

By dividing 5182 by 100 we get 51.82, which is the average fineness of the sand. This figure is not an index of the uniformity, since the same percentage might express the fineness of a well-graded sand, or of one whose grains were practically all one size.

C. W. Parmelee[1] took the sum of the percentages passing each screen and divided it by the number of screens used, which gave the *per cent of fineness.* As he points out, this method is comparable only with sands that have been screened by the same number of sieves and of the same size, since the per cent obtained varies with the number of screens used.

Ries[2], in testing Michigan molding sands, uses a method which gives the average size of the grains in a sand, thus providing a much better index of the fineness of the sand than either of the other methods offered. The results obtained from this method are comparable no matter how many screens or what size screens were used in testing the sands. In applying the method it is first necessary to compute an average size of the grains retained on each screen. This figure is then multiplied by the weight of sand retained on the screen and the sum of these products divided by the weight of the sample. The foregoing analysis illustrates the method:

Table showing method of derivation of the "average size"

Mesh	Average size in inches of grain retained on each screen	Weight of sand in grams retained on each screen	Product of screen mesh size by weight on screen
6	.158	2	.316
8	.112	3	.336
10	.079	6	.474
14	.056	8	.448
20	.0394	9	.3546
28	.0280	10	.2800
35	.0196	12	.2376
48	.0140	20	.2800
65	.0099	20	.1980
100	.0070	5	.0350
150	.0050	3	.0150
200	.0035	2	.0070
		100	2.9812

1 Kummell, H. B. and Hamilton, S. H., New Jersey Geol. Survey, Ann. Rept. for 1904, pp. 208-209, 1905.
2 Ries, Heinrich and Rosen, J. A., Michigan Geol. Survey, Ann. Rept. for 1907, pp. 50-51, 1908

By dividing 2.9822 by 100 we get 0.029822, which represents the diameter, in millimeters, of the sand grains, if all the grains in this sand were reduced to a uniform size. With this diameter all the grains would just pass a 35-mesh sieve.

FINENESS MODULUS

The fineness modulus is a term developed by Prof. D. A. Abrams[1] in an extended series of tests to determine the influence of size, grading, and water content of concrete mixtures on the resulting strength of the concrete. In calculating the fineness modulus, the following Tyler Standard sieves are used in determining the mechanical analyses of the sand or gravel: 100, 48, 28, 14, 8, 4, ⅜, ¾, and 1½.

The results are expressed in percentages of material coarser than each sieve. The sum of these percentages divided by 100 is the fineness modulus. In case the sieve analysis is expressed in percentages of material finer than each sieve, the fineness modulus may be found by subtracting their sum from 900 and then dividing by 100.

Sample calculations to determine fineness modulus

Mesh	Per cent coarser than each sieve								
	100	48	28	14	8	4	⅜	¾	1½
Per cent	89	82	72	62	51	38	25	11	0

The sum of the percentages equals 430.
430÷100=4.3, the fineness modulus of the sand

Mesh	Per cent passing each sieve								
	100	48	28	14	8	4	⅜	¾	1½
Per cent	11	18	28	38	49	62	75	89	100

The sum of the percentages equals 470.
900÷470=430; 430÷100=4.3, the finess modulus of the sand.

When the sand is tested by the old system of sieves the fineness

1 Abrams, D. A., Design and concrete mixtures: Struc. Mat. Res. Lab., Lewis Inst., Chicago, Bull. 1, 1919.

modulus is found by adding the percentages retained on the 4–, 10–, 30–, 50–, and 100-mesh sieves, and divide the sum by 100.

In a series of tests in which concrete composed of aggregates of varying grading, but with the same fineness moduli, was compared with concrete made of aggregates of varying fineness moduli, the influence of the coarseness of an aggregate was strikingly shown. From these tests it appears that the fineness modulus is a factor to be considered in determining the relative values of different sands and gravels and for that reason it has been determined for the sands investigated in this report.

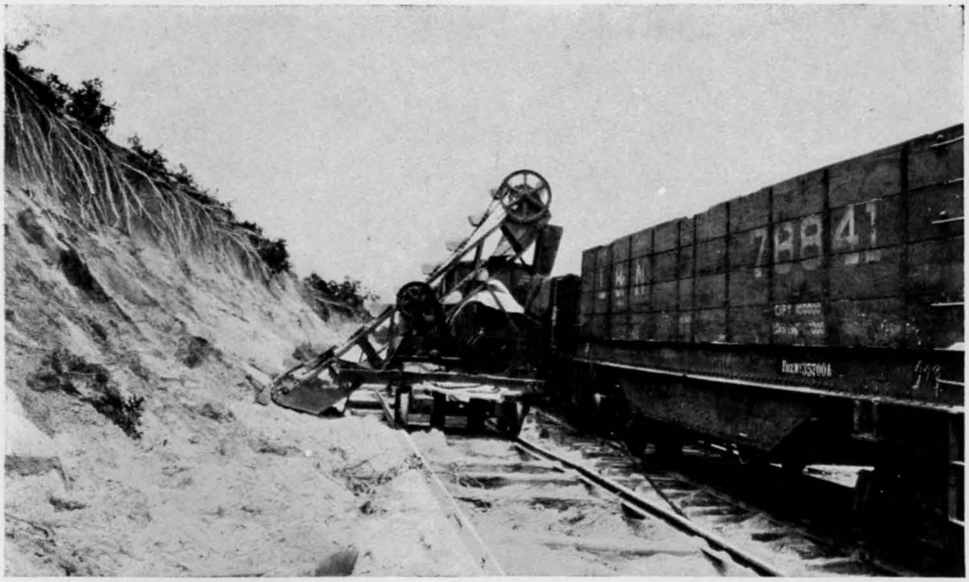
SHAPE OF GRAIN AND PEBBLE

Sand grains and gravel pebbles assume a variety of forms due to the rolling about they receive in stream beds, or to abrasion when carried by the wind, or by grinding action when carried by ice. In general, the more angular a grain or a pebble, the closer it is to its point of origin. Rounding is only acquired after being carried for long distances by the methods mentioned. In small mountain streams, near their head waters, the pebbles and grains are angular; in glacial deposits, or further down the course of the mountain streams, the pebbles become sub-angular; and finally, at great distances from their source, the pebbles are almost completely rounded. Grains of dune or desert sand, that have been blown about by the wind for long periods, are usually well rounded. Beach sands are more likely to be angular since it has been pointed out[1] that sand grains under 0.75 millimeter (35 mesh) in diameter can not be rounded under water. Except in a few subordinate uses, the shape of the grain or pebble has little significant influence on the value of sand or gravel.

DURABILITY OF GRAIN AND PEBBLE

The durability or resistance of sand grains and pebbles is largely a function of their mineral composition. Since quartz is the most resistant common mineral, sand grains composed principally of this mineral will be the soundest. Soft and easily soluble minerals such as gypsum and calcite, as well as minerals that readily tend to break up along cleavage lines, are not desirable components of commercial sands. Pebbles made up of soft, readily disintegrated, or readily decomposed rocks, produce gravels of little durability.

1 Zeigler, V., Jour. Geology, Vol. 19, pp. 645-654.



A. HAIST CAR-LOADER, J. R. HIME SAND COMPANY, JUNCTION CITY, GEORGIA

B. MINING GRAVEL BY GASOLINE SHOVEL MUSCOGEE COUNTY PIT, 3½ MILES EAST OF COLUMBUS

The durability of rock fragments and gravel may be found by testing in a Deval abrasion machine. This machine consists of a cylinder mounted at an angle of 30 degrees with its axis of revolution. Pieces of stone or gravel are put into the machine and shaken by its revolutions. The weight of the material that is worn off after 10,000 revolutions, and which passes $\frac{1}{16}$-inch mesh, expressed as the percentage of the weight of the original charge, is the measure of abrasion of the stone, and is called the "per cent of wear." Wear is also expressed by the "French coefficient of wear," arbitrarily derived by dividing 40 by the per cent of wear.

In testing Canadian gravels for abrasion, L. Reinecke[1] describes two methods used in the laboratories of the Canada Department of Mines. In the first method 5000 grams of the run-of-bank gravel, screened to pass a two-inch screen and retained on a ½– inch screen, was put into the machine and the per cent of wear determined. The other method consisted in separating the gravel into the following sizes: ¼ - ½ inch, ½ - ¾ inch, ¾– 1 inch, 1 - 1¼ inch, 1¼ - 1½ inch.

Five hundred grams of each size were taken and run separately in the abrasion machine with 20 steel balls, 1 inch in diameter, for 5,000 revolutions and the per cent of wear calculated as previously described. In the first method the influence of the grading factor on the wear is considered, and in the second this is eliminated.

Objection to the Deval machine, in its usual form, is raised on the ground that the dust, abraded from the stone fragments, acts as a cushion and prevents as great an amount of wear as would occur if the dust were gotten rid of as fast as it is formed. An alteration in the machine, consisting of narrow slots running lengthwise to the machine and permitting the dust to pass out as it is produced, has recently been devised, and is in use in many of the road material testing laboratories.

CEMENTING VALUE

The most desirable property of a gravel to be used in gravel roads is its bonding power or cementation. The action of water on the fine rock particles and clay in a gravel road bed forms colloidal or gluelike materials, which cement the gravel, and form hard surfaces in

1 Non-bituminous road materials: Econ. Geology, Vol. 13, p. 588, 1919.

wet or dry weather. It has been shown[1] that when rock powders are ground with water in a ball mill, alkaline hydroxydes and free silicic acid are generally formed, causing the deposition of a gummy substance on the fresh mineral particles. This material, whose particles have been studied in detail, is believed to be colloidal substance formed by the action of water on the rock powders.

To test[2] for the cementing value of a gravel, 500 grams of the material which passes a ½-inch screen is ground with 90 centimeters of water for 5,000 revolutions in a small ball mill. The dough is then removed and made into briquettes, 25 millimeters in diameter and 25 millimeters in height, in a special hydraulic briquetting machine. The briquettes are dried for 20 hours in room temperature and for 4 hours in an air bath at 100°C. They are then cooled in a dessicator, and broken by the blows of a one kilogram hammer falling through a vertical distance of one centimeter. The number of blows needed to destroy the resilience of the briquette is considered the cementing value of the gravel. Georgia gravels included in this report were not subjected to this test.

VOIDS

The term *voids* refers to the porosity, or the total space between the grains of a sand. A knowledge of this factor is thought to be necessary when the sand is to be used for concrete purposes. The percentage of voids depends on the grading of the grains. According to Slichter,[3] in sands where the grains are of uniform size the voids will be greatest. Even though the grains be uniform spheres, the voids percentage will differ with their arrangement from 47.65 per cent to 25.95 per cent. The porosity, however, is independent of the size of the grain, if the grain size is uniform throughout the sand. A sand composed entirely of 20-mesh grains has the same porosity as a sand made up of 100-mesh grains, provided the grains are similarly arranged in both sands. In the coarser sand there will be fewer, but larger pores, and in the finer sand there will be more, but smaller pores.

In well-graded sands smaller grains will fill the spaces between the largest, and still smaller ones will occupy the remaining interstices,

1 Cushman, A. S., The effect of water on rock powders: U. S. Dept. Agr., Bur. of Chem., Bull. 92, 1905.
2 Reinecke, L., Econ. Geology, Vol. 13, p. 566, 1919.
3 Slichter, Chas. S., The motions of underground waters: U. S. Geol Survey Water Supply Paper 67, p. 20, 1902.

until in some sands the voids percentage may be as low as 10 or 15 per cent. Coarse sands are more likely to be better graded than fine sands, hence their voids are usually less. Such sands are considered desirable for concrete, since they leave fewer spaces to be filled with cement and thus produce a strong concrete with less cement than a poorly graded sand would require.

The value of voids determination for concrete sands is questioned by many engineers due to frequent opportunities for errors arising from the conditions under which they were made and from incorrect application in practical work.

The percentage of water or moisture in sand influences its volume, since the water forms a film around the grains, forcing them apart and increasing the volume and pore space of the sand, and causing a moist sand to weigh less than a dry sand. The voids increase by 25 per cent of their original percentage, as water up to 7 per cent of the weight of the sand is added. The voids percentage found in the laboratory in a dry sand sample is therefore of little value unless the actual amount of moisture is known in the sand which is to be used in construction work. It has also been frequently pointed out that the voids percentage in a sand is not an accurate indication of the effective voids in the sand after mixing with cement and water. In practiec, the volume of gravel is not nearly so much affected by moisture as is sand, since gravel rarely takes up more than two per cent of moisture.

Difficulties in the exact determination of voids in the laboratory will be brought out as the different methods are described.

METHODS OF DETERMINATION

A field approximation of the voids percentage of a sand or gravel may be made by filling a bucket, of known capacity, level full with the sand or gravel to be tested. The material should be allowed to fall from the same height and at the same rate, and the container should either be given a few taps, an equal number with each sample, to settle the sand, or else none at all, in order that the sand will not be unequally compacted in different samples and incomparable results obtained. When the sand container is full, a known volume of water is added until the water is also even with the top of the bucket. The percentage of the volume of water to that of the bucket is the voids percentage by volume. This result, however, is inaccurate, since considerable air may still remain in the sand pores which has not been forced out by the water. If the bucket is marked at a certain content then only a certain amount of sand need be put in and the sand and water can be agitated to permit complete saturation by the water.

In the laboratory more exact methods can be used. Dake[1] describes a method used at first in testing Missouri sands. A measured volume of water was poured into a graduated tube. Into a similar tube, a measured volume of sand dried at 110°C., was slowly poured without shaking down. This sand was then poured slowly into the measured quantity of water in order that no air would be included with the grains. The mixture of sand and water was tapped until no further settling results and its total volume read on the graduate. The height of the sand surface was also read, or the volume of the wet, compacted sand including pore space. With these data the porosity of the wet, packed sand, and the dry, unpacked sand can be found, The following formula is given for finding the porosity of the wet. packed sand:

$$\text{Voids} = \frac{Vw - (Vt - Vs),}{Vs} \text{ in which}$$

Vw = volume of the water in the tube before adding sand
Vt = total volume of sand and water in the tube
Vs = volume of sand wet and compacted (including pore space) whence
(Vt — Vs) = volume of water above compacted sand, and
Vw — (Vt — Vs) = water in the pores of the sand (the total water less the water above the sand), or
Vw — (Vt — Vs) = actual porosity in the wet packed sand, whence

$$\frac{Vw - (Vt - Vs)}{Vs} = \text{proportion of porosity in wet packed sand}$$

The following formula is used to get the porosity in the dry unpacked sand:

$$\text{Voids percentage} = \frac{Vw - (Vt - Vd)}{Vd} \times 100, \text{ in which}$$

Vd = the volume of dry sand, all the other symbols being the same as in previous formula

As pointed out by Dake there is a tendency to stratification when the sand is poured into the water. Since stratification forms layers of equally sized grains, the voids in these layers would be greater than if the different grains were thoroughly mixed. Thoroughly mixing before adding to the water and a minimum fall to the water will help to minimize this error.

1 Op. cit., pp. 22-24.

The water might be poured into the sand but an error of greater magnitude in the opposite direction is produced, since air will remain in the pores, thus preventing complete saturation by the water. Dake found that in tests of this kind, after standing five hours, air bubbles that could not be shaken out still persisted. He also found in several tests of the same coarse-grained sand, differences of two per cent in the pore space, but with fine sand the results of the latter method are more unreliable. With moderately fine-grained sand, by pouring the sand into the water, tests on the same sand differed by less than two per cent in three tests, but when the water was poured into the sand, three trials differed from each other by over four per cent and ran from three to six per cent lower than when the sand was poured into the water. Dake also found that if small samples (under 100 cc.) were used in the voids determination the results showed differences of from 2 to 5 per cent, but in samples of 300 cc., or larger, repeated trials checked to within ½ to 2 per cent. The smaller samples showed less porosity.

Another method frequently used in sand-testing laboratories, which obviates the inaccuracies of the foregoing methods, is to introduce the water into the sand-containing vessel from below. In a variation of this system described by R. L. Humphrey[1], a percolator about three inches in diameter is used, having a funnel-shaped orifice at the bottom, which is connected by a rubber hose to a graduated burette standing higher than the percolator. A small, perforated, porcelain dish or strainer fits over the opening in the bottom of the percolator. A given quantity of the sand for determination is placed in the apparatus, filling it to a mark which indicates a definite volume. Water is allowed to fill the tube and percolator until even with the strainer to avoid compution of the water in the tube. The level of water in the burette is then read, and water is allowed to enter the percolator from the bottom until it reaches the top of the sand. The difference in the burette readings equals the amount of water required to fill the voids in the sand. The percentage of voids can be computed from the following formula:

$$C = \frac{Vw}{Vb} \times 100, \text{ in which}$$

Vw = volume of water introduced
Vb = volume of sand in percolator
C = percentage of voids

1 Am. Soc. for Test. Mat. Proc., Vol. 6, pp. 405-411, 1906.

Although this method reduces the error due to included air bubbles, it does not entirely exclude the air, and results from it will, therefore, be lower than actual. If the water is introduced fast enough to agitate the sand, slightly better results are obtained.

For the determination of voids in gravels by these methods, large containers must be used. In the cone-specific-gravity method[1], a truncated steel cone, 10 inches in over-all height, 10 inches in over-all diameter of the bottom, and 3 inches inside opening at the top, is filled with gravel which is completely compacted and kept full until no more gravel can enter. The following formula is used:

$$1 - \frac{C - A}{(B - A)\ D} \times 100 = \text{percentage of voids, in which,}$$

A = weight in grams of empty cone
B = weight in grams of cone filled with clean water
C = weight in grams of cone filled with compacted aggregate
D = specific gravity of the aggregate

In testing Georgia sands, none of the previously described methods were used, but the voids were computed from the specific gravity of the sand which had already been found after the method described on page 40. In the case of a sand whose specific gravity was 2.66, which is the average specific gravity of sand, 100 cc. of the sand should weigh, if it were solid, 266 grams. On account of the voids in the sand, however, it will weigh much less, let us say 160 grams. The difference, then, between the actual weight of the sand and its weight if no voids existed, represents the weight of sand needed to fill the voids in the sample.

266 grams — 160 grams = 106 grams of sand required to fill the voids

$$\frac{106}{266} \times 100 = 39.8 \text{ per cent voids}$$

The percentage of this figure to the solid weight of the sand is the voids percentage, since the weights are in proportion to the volumes. The formula is as follows:

$$\frac{(V \times S.G.) - W}{V \times S.G.} \times 100 = \text{voids percentage, in which,}$$

V = volume of sample in centimeters
S. G. = specific gravity of sample
W = weight of sample in grams

1 Blanchard, Arthur A., Elements of highway engineering, pp. 494, 495, 1915.

In construction work it may be more convenient to weigh a cubic foot of sand, in which case the formula is as follows:

$$\frac{(V \times 62.5 \times S.G.) - W}{V \times 62.5 \times S.G.} \times 100 = \text{voids in which,}$$

V = volume in cubic feet
S. G. = specific gravity
W = weight in pounds
62.5 = weight in pounds of one cubic foot of water

In finding the weights of 100 centimeters of different sands considerable range in the compacting powers of the different sands was noticed; so that in order to insure as comparable results as possible, the container was tapped against the palm of the hand, as the sand was added, until the volume was 100 centimeters and the sample was then weighed. Compacting produced changes in the voids percentage ranging from 5 to 25 per cent of the total percentage, depending on the grading of the sand. The use of the weight of 100 centimeters upon which to base the voids percentage of a sand, gives accurate results, since a difference of 0.1 gram in the weight of 100 centimeters of sand makes a difference of only 0.03 per cent in the voids percentage.

SPECIFIC GRAVITY

The specific gravity of sand depends entirely upon its constituent mineral or rock fragments. A pure quartz sand will have a specific gravity of about 2.65 to 2.66. Any appreciable variation from this shows impurities. A magnetite sand may have a specific gravity as high as 6.18. Very often the heavier minerals have a harmful influence on the strength of mortar, since they may split up and decompose. Some Missouri sands[1] show a low specific gravity which has been attributed to the porous and decayed condition of the chert grains which occur in large amounts in these sands.

Table showing specific gravity of sand grain minerals

Quartz	2.653 — 2.66
Flint, Chert	2.60 — 2.64
Feldspars	2.50 — 2.9
Orthoclase	2.57
Kaolinite	2.60 — 2.63

1 Dake, C. L., The sand and gravel resources of Missouri: Missouri Bureau of Geol. and Mines, Vol. 15, 2d ser., p. 18, 1918.

Limonite	3.6 — 4.0
Hornblende	2.9 — 3.4
Olivine	3.26 — 3.4
Calcite	2.71
Lignite	1.15 — 1.3
Chromite	4.5 — 5.0
Rutile	4.18 — 4.25
Zircon	4.5 — 4.7
Magnetite	5.17 — 6.18
Monazite	4.19 — 5.3

Although the specific gravity of a sand is not necessary in testing, it is of value in computing the very important factor of voids content, and for that reason it has been included in the tests in this report. The average specific gravity of Georgia sand is 2.66.

METHODS OF DETERMINATION

In testing Missouri sands Dake[1] first used an ordinary graduated tube. A measured quantity of water was put into the tube and into this 100 grams of sand were poured, and the mixture of sand and water thoroughly shaken to remove included air bubbles. The new height of the water was then noted and the data used in the following formula:

$$S.\ G. = \frac{W}{Vt - Vw}, \text{ in which}$$

W = weight of dry sand in grams
Vw = Volume of water in tube in cubic centimeters
Vt = total volume of sand and water in the tube in cubic centimeters

The graduate was read to the nearest cubic centimeter and interpolation to tenths was tried, but it was impossible to read the volume closer than 0.3 cc. These results gave variations of from 0.01 to 0.06 in the specific gravity of the sand which were considered too large. To increase the accuracy of the determination a Le Chatelier bottle was used.

A Le Chatelier apparatus was also used in finding the specific gravity of Georgia sands. It has a large, globular base, into which 50 grams of sand were placed, and a long, narrow, graduated neck, thus permitting very sensitive readings of the liquid. Since many of the sands tested contained clay in amounts large enough to produce a slight foam at the top, which gave trouble in reading the meniscus, gasolene was used instead of water. A sharp reading could then always be obtained, and the bottle cleansed itself much more readily after

1 Op. cit., p. 19.

each sand than when water was used. The formula given above can be used with this method.

When doubt existed as to the results obtained by the Le Chatelier apparatus, particularly in fine-grained sands, a picnometer bottle was used. The picnometer is a small, globular-shaped bottle, with a perforated stopper, which permits the water to overflow when it is inserted, so that the bottle is always filled to the same point. The weight of the picnometer empty, and full of water, is then found, and a known weight of sand is placed in the bottle which is filled with water and weighed, care being taken to exclude air bubbles. To get the best results a constant temperature should be maintained when using this apparatus. It will give results accurate to within five thousandths. The following formula is used to find the specific gravity[1] by this method:

$$\frac{Ws}{(Ws + Wb) - Wt} = \text{specific gravity}$$

Ws = weight of sand (in grams)
Wb = weight of bottle filled with water only (in grams)
Wt = total weight of bottle with sand and water (in grams), whence
Ws + Wb = the total weight of the substance involved, and
(Ws + Wb) — Wt = weight of the water displaced, and hence its volume.

The specific gravities of Georgia sands are listed in the tables. The average for all the sands tested was 2.66. To get the specific gravity of gravels or coarse aggregates, the specific gravity of material over ½ inch and under ½ inch in size is separately determined, and the specific gravity of the whole can be calculated, if the proportion of the materials of these sizes is known[2].

WEIGHT OF SAND AND GRAVEL

The weight of sand and gravel is valuable as a guide in certain transportation questions; in proportioning sand and gravel of one kind with other kinds, or with other materials; and in converting one unit of measurement into another. The weight is usually given in pounds per cubic foot or pounds per cubic yard. Sand and gravel are generally sold by the ton or by the yard. Dealers may wish to

1 Op. cit., p. 21.

2 Hubbard, Prevost, and Jackson, F. A., Jr. The specific gravity of non-homogenous aggregates. Proc. Am. Soc. Test. Mat. Vol. 16, Pt. 2, pp. 378-402, 1916.

See also Am. Soc. Test. Mat. Proc. Vol. 17, pt. 1, pp. 776-778, 1917.

convert tons into yards, or yards into tons, to fix an equal price for their product when sold on either basis. To convert yards into short tons it is necessary to know the weight per cubic yard of the sand. This can be actually determined for the sand in question or an average figure can be taken. The United States Geological Survey[1] has computed the average weight of a yard of sand to be 2665 pounds and the average weight of a yard of gravel to be 2820 pounds. The average weight per cubic yard of 150 samples of Georgia sands was 2660 pounds.

Taking the average weight of a cubic yard of sand from the Federal Survey's estimate, 2665 pounds, and dividing it by 2000 we get 1.33, or the number of short tons in a cubic yard of sand. To convert 300 yards of sand, for example, into short tons we multiply 2665 by 300 and get 799, 500 pounds, which we divide by 2000 and find 399.7 short tons. To convert short tons into yards we divide 2665 into the total number of pounds in the quantity in question. To find the value of a ton of sand selling at $1.30 a yard, we multiply $1.30 by 2000, getting 2600, wh'ch we divide by 2665 and get $0.97½ as the value of a ton.

METHODS OF DETERMINATION

The simplest way to find the weight of sand is to fill a box of known volume and weight, with the sand or gravel and then weigh the box, the difference in weight equalling the weight per unit of sand. Care must be taken, however, to see that the sand is added to the container in the same way for each sample and that it receives just the same amount of packing, else the results will not be comparative. Different persons in finding the weight of the same sand will invariably arrive at different results unless each takes great care in performing the operation in the same manner. Differences in weight of the same volume of sand of from 3 to 25 per cent are possible, depending on whether or not the sand is shaken down as it is added to the container.

In this report the volume weight of sand was found by weighing to the nearest tenth of a gram, 100 cubic centimeters of thoroughly dried sand in a bottle after completely settling the sand as it was added, by tapping the bottle against the palm of the hand, and then multiplying this weight by a factor depending on whether the weight of a cubic foot or a cubic yard was desired.

Since there are approximately 28,317 centimeters in a cubic foot, then the weight in grams of a cubic foot of sand may be found by multi-

1 Stone, R. W., U. S. Geol. Survey Mineral Resources, 1918, p. 314, 1919.

plying the weight of 1 centimeter by 28,317, or the weight of 100 centimeters by 283.17. This number of grams can then be converted into pounds by dividing by 453.3, the number of grams in a pound. The actual weight in pounds of a cubic foot of sand can be found directly by multiplying the weight of 1 centimeter in grams by 62.5, which represents the two combined factors. To find the weight of a cubic yard, simply multiply the weight of a cubic foot by 27. An accurate determination of the weight of a cubic foot based on so small a sample as 100 cubic centimeters is possible, since a difference of one-tenth of a gram in the weight of 100 centimeters only affects the weight of a cubic foot by 5 ounces.

MORTAR TESTS OF SAND[1]

Actual tests, to determine the tensile, transverse, and compressive strengths of the concrete a given sand will make, are the most satisfactory, and they should be made in all important work, when there is sufficient time. However, only those who are experienced in the hand mixing of mortar should make the tests, as there is a knack in properly mixing the materials, and the amount and manner of puddling and ramming is so important that the results of tests by inexperienced persons will be practically valueless.

The strength of the concrete made from the unknown sand is compared with the strength of concrete made from a standard sand, and this proportion reduced to percentage is known as the "strength ratio" of the sand. In the United States, natural Ottawa (Illinois) sand, screened to pass 20 mesh and retained on 30 mesh is used for this purpose.

The *tensile strength* is generally found in mortar tests, since it requires simple apparatus and is easily made, although, consistent accurate results are sometimes hard to obtain and the test itself is not of much practical application, nevertheless it serves very well for comparative testing. It is made by subjecting a mortar briquette, which is of 1-square-inch cross section at the center, and bulged at the ends, to tension induced at the ends.

Transverse strength, or modulus of rupture, is of less importance than the crushing strength, but due to the greater ease of making both

1 For detailed description of mortar tests see Taylor and Thompson, op. cit., pp. 343-348.

this test and the tension test, it is more frequently made. The tension and transverse tests serve, when made comparatively with some standard sand, to show the proportionate values of different sands.

Compression tests are usually made on cylinders of concrete, whose heights are twice their diameters. These cylinders are subjected to pressure in a hydraulic compression testing machine. The machine is quite expensive and although these tests are probably of more value in showing the actual strength value of the concrete, they are not used generally in testing sands.

THE USES OF SAND AND GRAVEL

BUILDING SAND AND GRAVEL

Sand and gravel used in concrete; sand used for brick mortar and plaster; and roofing gravel, are included in this report under building sand and gravel. Approximately 73 per cent or 282,165 tons, of the sand and gravel commercially produced in Georgia during 1919 has been used for these purposes. Almost every one has had occasion to use sand for such work, and hence an enumeration of its requirements should aid in making a selection of materials when a choice is possible.

CONCRETE AGGREGATE

With the advent of concrete roads, and the ever-increasing use of concrete for practically all building purposes, a consideration of the fine aggregate, or sand, and the coarse aggregate, which may be gravel, broken stone, slag, cinders, or broken bricks, becomes necessary if economical and durable results are to be obtained. Until within the last ten years very little attention had been given to the matter of determining what constituted good concrete aggregate. Tests were restricted to a casual inspection and rarely, if ever, was the sand or gravel made in concrete briquettes and subjected to tension and compression tests. At present the Federal government and some of the State governments, as well as the Portland Cement Association, numerous universities and private laboratories, are making elaborate tests on sands and gravels not only to determine those tests of most practical value, but to actually determine which of a number of equally available aggregates will prove most economical and lasting.

In Georgia, the Road Materials Testing Laboratory, at the Georgia School of Technology, in Atlanta, makes thorough tests of sand and gravel for which a nominal charge is made to cover the expense of the work. Tests for building and road sand and gravel are made free of charge at the Bureau of Public Roads, and tests of molding sands at the Bureau of Standards, both at Washington, D. C.

Testing of the sand should not be confined merely to the selection of the best pit, but it should be continued on each shipment of the material to the construction work. With a knowledge of the size of the grains a great saving can frequently be affected by combining two cheaper sands and thus substitute sand or stone for more expensive cement without reducing the desired strength of the concrete.

Due to its bulk, rarely more than a day's supply of aggregate can be stored near the work, consequently there is not sufficient time to make mortar tests, involving at least 7 days; nevertheless, the need for such tests exists. To take the place of such long tests, shorter tests, based on the relation between the grain sizes of the sand and the mortar strength, have been devised. By applying these methods the quality of each carload or shipment of sand can be quickly found. Such tests, however, should not replace mortar tests when there is plenty of time. In small jobs, requiring only a few wagon-loads of material, elaborate testing would of course be unwise; nevertheless, no job is too small to neglect the application of a number of easily applied field tests. Very often a few hours additional search or inquiry will disclose sand much more desirable, and such a search is certainly not wasted, when the effect of the aggregate upon the resulting concrete is so marked.

SAND

In general a good concrete sand should conform to the following requirements:

1. The grains should be coarse, $\frac{1}{8}$ to $\frac{1}{4}$ inch, with a smaller amount of fines (under $\frac{1}{8}$ inch), rather than all fines. Sands whose grains are mostly under $\frac{1}{32}$ of an inch will require twice the cement a coarse sand would require to make a concrete of equal strength[1]. Uniform grading of the grains may be desirable but not necessary; coarseness is the most important quality.

2. Vegetable matter even in minute quantities is particularly injurious in a mortar sand.

3. Clay and silt exceeding 8 to 12 per cent is also harmful in sand, although where the local supply is limited, a high-clay sand, or dirty sand, may be used in very small and unimportant work rather than to incur the expense of shipping in more desirable sand.

The U. S. Bureau of Public Roads reccommends the following specifications for sand for use in first class concrete:

> "All to pass a $\frac{1}{4}$-inch sieve, to have at least 20 and not more than 50 per cent retained on a 20-mesh sieve, at least 80 per cent retained on a 50-mesh sieve, and at least 97 per cent retained on a 200-mesh sieve.
>
> "To have a tensile strength ratio, when compared to standard Ottawa sand mortar briquets, of at least 100 per cent."

---

1 Taylor, F. W. and Thompson, S. E., Concrete, plain and reinforced, 2d. ed., p. 159 a, 1911

For concrete of the second class the following are suggested:

"All to pass a ¼-inch sieve, to have not more than 80 per cent retained on a 20-mesh sieve, and to have at least 50 per cent retained on a 50-mesh sieve, and at least 95 per cent retained on a 200-mesh sieve.

"To have a tensile strength ratio, when compared to standard Ottawa sand mortar briquets, of at least 75 per cent."

GRAVEL

1. The pebbles should be composed of durable unrotted material, not likely to disintegrate when subjected to the pressure of the settling concrete.

2. The gravel should be entirely free from vegetable matter and contain as little clay or silt as possible. What clay or silt exists in the gravel should be uniformly distributed through it.

3. Coarse pebbles with a maximum of 2½ inches in diameter are desired.

The U. S. Bureau of Public Roads suggests the following specifications for gravel to be used in concrete aggregate:

"All to pass a 1½-inch screen and to be retained on a ¼-inch screen, and to have at least 25 and not more than 60 per cent retained on a ¾-inch screen."

For emphasis and convenience of discussion, the following characteristics of the concrete aggregate will be considered: Size of grain and impurities, which include the clay, organic matter, and mineral and chemical content.

SIZE OF GRAIN

Numerous tests of various sands have shown conclusively that the relative proportions of grains of different sizes have a great effect on the strength of the mortar produced from the sand and also upon the quantity of cement required to produce a mortar of given strength. Many of these investigations have indicated that the grading should be uniform — that is, the sand should contain as nearly as possible equivalent amounts of each size grain from ¼ inch down to 100 mesh.

Fuller and Thompson[1] after making numerous tests of differently graded aggregates arrived at the following conclusions of which an abstract of those affecting sand and gravel is given:

---

1 Fuller, W. B., and Thompson, S. E., Laws of proportioning concrete: Am. Soc. Civil Eng. Trans., Vol. 59, pp. 67-143, 1907.

1. Stone of largest size makes strongest concrete; a graded mixture, in which the maximum size of the stone is 2½ inches in diameter, gives stronger concrete than a mixture where the maximum stone is 1 inch in diameter.

2. Aggregates in which particles have been specially graded in sizes, produce cements of higher strength than mixtures of cement and natural material in similar proportions. The average improvement in strength by artificial grading under the conditions of the tests was about 14 per cent. Comparing the tests of strength of concretes having different percentages of cement, it was found that for similar strengths the best artifically graded aggregate would require about 12 per cent less cement than a like mixture of natural materials.

3. The strength and density of concrete is affected by the variation in the diameter of the particles of sand more than by variation in the diameter of the stone particles.

4. An excess of fine or of medium sand decreases the density and also the strength of concrete, but a deficiency of fine grains of sand in a lean concrete decrease the strength of the concrete.

5. The best mixture of cement and aggregate has a mechanical analysis curve resembling a parabola, although the ideal mechanical analysis curve is slightly different for different materials.[1]

The tabulated results of mechanical analyses of an aggregate are practically meaningless to many. Curves have been devised, which show at a glance the granulometric composition and which afford means of comparing the grading of two or more sands.

In Fig. 1 the curve represents approximately a granulometric analysis of so-called ideal uniformity[2]. The character of other sand curves, so far as their uniform grading is concerned, shows up favorably or unfavorably as compared with the ideal curve.

Chapman and Johnson[3] have shown how a considerable saving may be effected by using a cheaper and poorly graded sand, if the lacking grades are supplemented by the addition of sufficient stone screenings or other sand to produce an artificial mixture whose grading approximates that indicated by the ideal curve. In the particular case in

---

1 Op. cit., pp. 192-193.
2 After Fuller, W. B., in Taylor, F. W. and Thompson, S. E., op. cit., p. 183.
3 Chapman, C. N., and Johnson, N. C., Economic side of sand testing: Eng. Record, Vol. 71, pp. 734-737 (correction p. 813) 1915.

A. KEYSTONE EXCAVATOR USED IN LOADING TRUCKS, RICHMOND COUNTY GRAVEL PIT, COLUMBUS

B. MINING SAND BY DRAG-LINE SCRAPER, J. R. HIME SAND COMPANY, JUNCTION CITY, TALBOT COUNTY question, sand A, a naturally well-graded sand, could be obtained for $2.24 a ton including freight, while the poorer sand, B, cost only $1.92. Stone screenings cost $0.88 a ton, and the cost of mixing them with the sand was about 3 cents a yard.

To determine the amount of each type of sand needed to form the artificial mixture, it is necessary to plot the mechanical analyses of the sands on the ideal curve (See fig. 1). From the diagram we see that the ideal grading curve cuts, let us say, the 40-mesh ordinate at 78 per cent; the analysis of the cheaper sand cuts this ordinate at 40 per cent and the analysis of the stone-screenings curve at 90 per cent making the difference between the ideal curve intersection and that of the two aggregates respectively 38 per cent and 12 per cent. Each of these differences are then divided by their sum to determine the proportion of each necessary to make an ideal mixture, which in this case is 76 and 24 per cent respectively. The process is repeated for all mesh sizes and the average taken. This figure then shows the proportion of screenings and sand to be used to make a mixture conforming to the ideal grading. In this way a sand capable of producing a concrete conforming to the specifications can be obtained at a smaller cost than if the naturally well-graded sand was used.

Feret[1] made a large number of experiments to determine the relation between the grain sizes of sand and the compressive strength of mortars. He divided the sand into three sizes corresponding to the mesh sizes, which he called coarse, medium, and fine:

Coarse------Passing 5 mesh and retained on 15 mesh
Medium----passing 15 mesh and retained on 46 mesh
Fine--------passing 46 mesh and retained on

By combining various amounts of each size and testing the strength of the mortar made from the combination he found that the densest mortars "are those in which there are no medium grains, and in which the coarse grains are found in a proportion double that of the fine grains, cement included."

Taylor and Thompson[2], in commenting on Feret's method, say that the method is undoubtedly valuable for sand-mortar mixtures but that for concrete mixtures having coarse aggregate to be con-

1 Feret, R., Annales des Ponts et Chaussees II, p. 182, 1892. See also Taylor, F. W., and Thompson, S. E., Concrete, plain and reinforced, pp. 155-162, 1916.
2 Op. cit., p. 192. (Footnote)

sidered, more than two sizes of materials are theoretically necessary to obtain the densest mixture.

Recently, the relation between the surface area of the sand grains and the amount of cement required to produce a mortar of given strength has been emphasized. Of two sand grains the larger will have less surface area, in proportion to its volume, than the smaller. The total surface area of a given volume of coarse sand will be much less than the surface area of the same volume of fine sand. A large surface area requires more cement to produce a given mortar strength than a small area, because a larger area must be coated with cement, and more points of contact exist between the grains which must be bridged over with cement. Edwards[1] has made a number of tests which show that a given cement mix will produce the strongest concrete with sand of the least surface area. This paper illustrates the method of proportioning the mix, in practice, by curves.

Quite recently Professor Abrams[2] has produced evidence which appears to show that the usual methods of proportioning concrete by sieve analysis of aggregates are open to considerable error. His conclusions were reached after three years of experimenting during which many thousands of tests were made. Abrams emphasizes the necessity of using coarse sand or a coarse total aggregate, which is really another way of considering the surface-area principle, since the coarser the aggregate the less its surface area. A simple method of application to practical work, however, has been found. The conclusions reached, which affect the proportioning of the fine and coarse aggregate, are as follows:

1. The sieve analysis furnishes the only correct basis for proportioning aggregates in concrete mixtures.
2. A simple method of measuring the effective size and grading of an aggregate has been developed. This gives rise to a function known as the "fineness modulus" of the aggregate. (See page 31).
3. The fineness modulus of the aggregate furnishes a rational method for combining materials of different size for concrete mixtures.
4. The sieve analysis curve of the aggregate may be widely different in form without exerting any influence on the concrete strength.
5. Aggregates of equivalent concrete-making qualities may be produced by an infinite number of different gradings of a given material.
6. Aggregates of equivalent concrete-making qualities may be produced from materials of widely different size and grading.
7. In general, fine and coarse aggregates of widely different size or grading can be combined in such a manner as to produce similar results in concrete.

---

1 Edwards, L. N., Am. Soc. for Test. Mat. Proc., Vol. 18, pt. 2, p. 235, 1918.
2 Abrams, D. A., Design of concrete mixtures: Struc. Mat. Res. Lab., Lewis Inst., Chicago, Bull. 1, 1919.

8. The aggregate grading which produces the strongest concrete is not that giving the maximum density (lowest voids). A grading coarser than that giving maximum density is necessary for highest concrete strength.
9. The richer the mix, the coarser the grading should be for an aggregate of given maximum size; hence, the greater the discrepancy between maximum density and best grading.
10. There is an intimate relation between the grading of the aggregate and the quantity of water required to produce a workable deposit.
11. The water content of a concrete mix is best considered in terms of the volume of the cement — the water-radio.
12. The shape of the particle and the quality of the aggregate have less influence on the concrete strength than has been reported by other experimenters.

These conclusions present an entirely new understanding of the functions of the sand and gravel in a concrete mix. Although the importance of good grading in the coarse and fine aggregate is still apparent, it is of less force than the necessity of having a coarse sand as shown by the fineness modulus (See fig. 4), together with the least amount of water necessary to produce a plastic and workable mix. Sand having a fineness modulus of less than 1.50 is undesirable as a fine aggregate in most concrete mixes, and sands whose fineness modulus exceeds 3.00 will generally give a concrete of normal strength ratio.

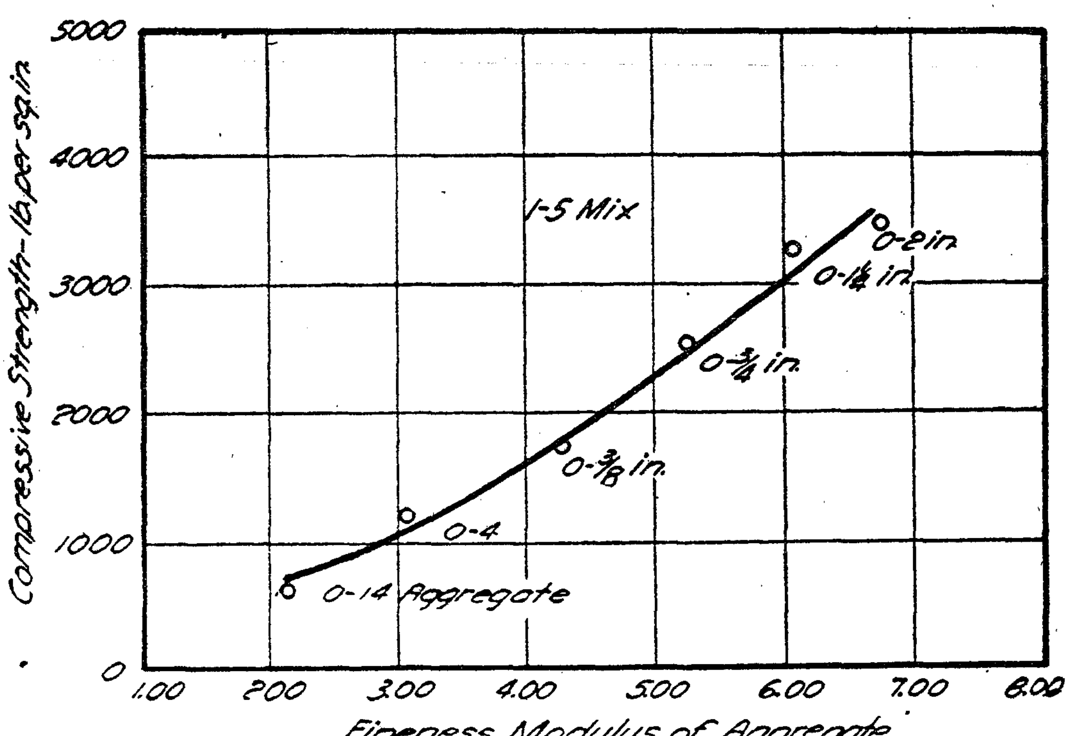


Fig. 4.—Relation between fineness modulus of aggregate and strength of concrete.

In applying these principles to concrete mixtures, the coarsest grained sand and the coarsest aggregate should not be used regardless of the richness of the mixture. The richer the mix the higher the fineness modulus of the sand may be that can be used with it; in lean mixtures the coarseness of the sand is limited.

Fig. 5 shows the maximum values of the fineness moduli of aggregates used in various mixes. In general the aggregate having the highest fineness modulus for the mix to be used will produce the strongest concrete.

For details regarding the method of proportioning coarse and fine aggregates of different fineness moduli, the reader is referred to the paper of Professor Abrams already cited.

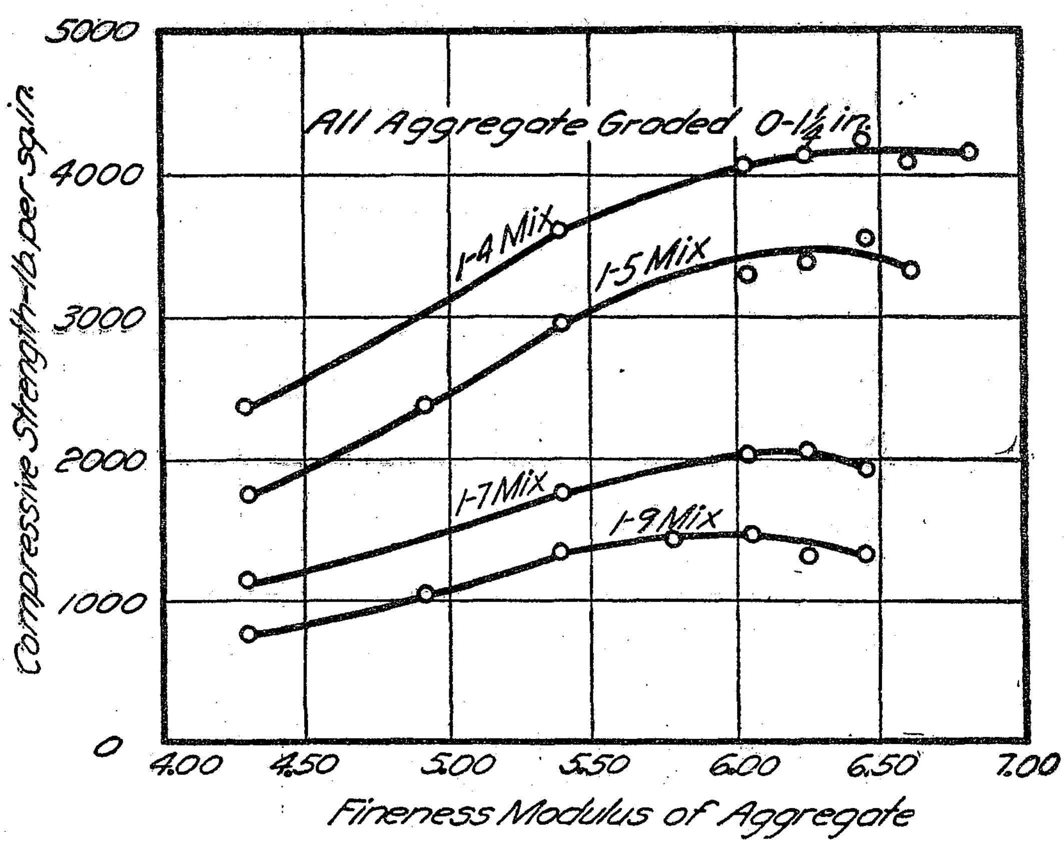


Fig. 5.—Relation between fineness modulus of aggregate and strength of concrete.

VOIDS

Since the percentage of voids of a sand depends on the grading, it is generally thought, when low, to indicate a good concrete sand. There is considerable doubt, however, whether the voids percentage of a dry sand is an accurate estimation of the voids in the sand when it is in concrete mix.

Tests of 34 sands selected at random from a much larger number made by the New York State Highway Department[1] from 1908–1910, show the sand having the least voids to be the best.

Jewett[2] believes a low percentage of voids does not give much indication of the value of a sand, unless accompanied by coarseness of grain. Withey[3], after testing 15 sands and fine aggregates, came to the conclusion that the laws of Feret could probably be applied to the tensile and transverse strengths of mortars as well as to the compressive strength. Although these experiments illustrated the value of well-graded sands, they showed no well-defined relation between mortar strength and either percentage of voids, uniformity coefficient, or percentage of silt.

The work of Abrams[4] would indicate that the value of the percentage of voids is not of major importance, unless the fineness modulus of the aggregate is high. In this report a determination of the voids of the various sands has been included.

Although a range of opinion regarding the grading of a concrete sand and gravel has been presented, the various ideas as to their effect on the strength of concrete only emphasize the importance of knowing the mechanical analysis of representative samples of the sand to be used in construction work. With a knowledge of the grading we can determine the value of the sand whether the theories of Fuller, Feret, or Abrams are favored.

Present knowledge indicates that a uniform grading is not the most desirable property of a concrete aggregate, but rather a minimum of surface area of the grains in proportion to the cement used. Coarse

---

1 Greenman, R. S., Practical tests for sand and gravel proposed for use in concrete: Am. Soc. for Test. Mat. Proc., Vol. II, p. 516, 1911.
2 Jewett, J. Y., Some sand experiments relating to per cent of voids and tensile strength: Am. Soc. for Test. Mat. Proc., Vol. 6, pp. 405-411, 1906.
3 Withey, M. O., Tests of mortar made from Wisconsin aggregates: Am. Soc. for Test. Mat. Proc., Vol. 13, pp. 834-857, 1913.
4 Op. cit.

sands best answer this requirement. The accompanying tables include calculations of the fineness moduli of Georgia sands, so that in less important work a simple comparison of the fineness moduli of sands from different localities may serve as an indication of the value of a concrete sand. For work involving a large money outlay, more refined application of Abrams' principles is desirable from the economic standpoint.

IMPURITIES

The impurities affecting a concrete sand or gravel are clay, (under which, silt, soil, and loam are here included), organic matter, and mineral grains other than quartz.

The subject of impurities in sand, or its "cleanness," has called forth much discussion. Tests have been made which seem to show that clay, silt, and even vegetable matter have little bad effect upon the concrete-making qualities of a sand. In fact some experiments have indicated the desirability of a high clay content in sand. Many of these results must be accepted with caution and some unconditionally rejected, however, and in all of them the conditions under which they were made should be considered. Thus, sand with a clay content of 20 per cent or even more, if used with a lean cement mixture, may make strong concrete, while sand with a small (3–10 per cent) clay content produces best results, if a rich mixture is used.

Taylor and Thompson[1] say "as a matter of fact it is impossible to make a general statement either to the effect that natural impurities in sand are beneficial or that they are detrimental. In some cases fine material may be of actual benefit, while in others the contrary is true."

CLAY

Clay has a more harmful effect in concrete made from natural cement than on that made from Portland cement. Sabin thinks amounts of clay up to 6 per cent are not harmful with either cement,[2] although with lean mixtures with Portland cement, clay, in amounts from 10 to 25 per cent of the sand adds to their strength,[3] and renders them more waterproof. Clay, however, is harmful in concrete which will be subject to immersion in salt water.[4]

---

1 Op. cit. p. 168.
2 Sabin, L. C., Cement and Concrete: 2d ed., pp. 319-320, 1907.
3 Op. cit., p. 271.
4 Op. cit., p. 364.

In a series of tests made by C. E. Sherman,[1] in which differing proportions of clay and loam were used with differing cements and sands, it was found that with other factors being equal, the resultant concrete strength increased with the proportion of clay in the sand. The 15 per cent clay mixture proved to be the strongest at the end of 6 to 12 months in 8 cases out of 12.

Hain[2] made a number of tests of washed and unwashed sands in which the washed sands gave poorer results than the natural material. He concludes that clay up to 12 per cent, if evenly distributed throughout the sand, is not harmful, but rather beneficial. Whether a sand need be washed should first be determined by actual mortar tests of both the natural and washed product, since the consideration of the saving on washing is important.

Other[3] tests showed that with a 1:2 mixture sand with an increasing clay content reduced the crushing strength of the mortar, but with a 1:3 proportion the strength of the mortar in general increased up to 15 per cent clay in the sand.

A small amount of clay in sand gives the concrete a smooth surface. Finely powdered clay when free from vegetable matter acts as a void filler and is said[4] to produce a more water-tight mortar. About 5 per cent of the weight of the sand is generally effective.

The harmful influence of reasonable amounts of clay, free from organic matter, in sand is likely to be over-estimated. To be on the safe side, tests of the mortar-making qualities of the sand should be made when time permits, since other factors may produce results that the amount of clay has not warranted. In specifying the amount of clay permissible in sand, it is wise to set a conservative limit, since with a high limit, some contractors may believe that little regard is held for a clean sand, and the limits are likely to be exceeded and very harmful organic matter also included.

The exhaustive tests of Abrams indicate that the less fine material, and consequently the less clay in a sand, the better. A large amount of clay, unless it is allowed to coat the sand grains, will require an excess of water in the mix. This water excess is probably harmful,

1 Effect of clay and loam on sand mortar: Eng. News, Vol. 50, p. 443, 1903.
2 Hain, J. C., Some tests of impure sand for concrete: Eng. News, Vol. 53, p. 127, 1905.
3 Griesenauer, G. J., Loam and clay in sand for concrete: Eng. News, Vol. 51, p. 413, 1902.
4 Taylor, F. W. and Thompson, O. E., op. cit., p. 301.

since it increases the amount of cement necessary to secure a desired concrete strength. On the other hand, clay coated grains, most certainly do not readily aid in the setting of the concrete, but hinder it. Numerous clay particles also increase the amount of cement needed, since there is a much greater number of contacts to be bridged by the cement.

The quality of "sharpness" so long included in sand requirements may be considered an index of the clay content, rather than of the angularity of the grain. Sand containing much clay, shale, or clay-coated grains, will not produce the grating peculiar to a clean, "sharp" sand when rubbed between the fingers, since the clay acts as a cushion between the grains. Although there is little reason why sand grains should be sharp[1] and the use of the term "sharpness" in specifications is condemned by many, it nevertheless is an important guide in a casual estimate of the clay or soft mineral content of a sand.

ORGANIC MATTER

Sometimes a sand that apparently conforms to all the requirements of an ideal concrete aggregate, produces mortar that does not give nearly the amount of satisfaction expected of it. The clay content has been small to negligible, the grading apparently perfect, yet something in it produces bad effects. This peculiarity has been attributed to organic or vegetable matter, generally in the form of a more or less visible brown coating of the grains, which prevents or hinders the complete setting of the concrete. The term loam has sometimes been used to refer to the organic matter in sand. Loam usually contains organic matter, but it is largely composed of clay and silt; the term organic matter as used here indicates true organic matter only. Such sands generally show in a chemical analysis a large amount of organic matter, and upon washing show marked improvement. It has been noted that the addition of small amounts of fertilizer to a clean sand gives low concrete tests.[2] Many defective sands will give different results if another brand of cement is used. In one instance the variation was from 20 to 80 per cent of normal strength, although analysis of the cements gave no clue.

Free[3] states that sand in swampy regions becomes coated with

1 U. S. Bureau of Standards, Circular No. 45, p. 36, 1913.
2 Freeman, J. R., Proposed study of concrete sands: Eng. News, Vol. 67, p. 1022, 1912.
3 Free, E. E., Proposed study of concrete sand: Eng. News, Vol. 67, p. 1024, 1912.

tannic and gallic acids, which hinder and even prevent the normal chemical action of the cement. Such material usually is in the colloidal form and can be removed by washing or by the addition of inorganic salts to flocculate it. The use of salt water has been suggested.

That the amount causing trouble in a sand is small is shown by the statement of Gaines[1] that 0.1 to 0.2 per cent organic matter is sufficient. Sands obtained from rivers running through regions in which coal or lignite occurs may contain injurious amounts of coal and lignite grains. Tan bark has been known to seriously affect the quality of river sands in which it occurs. Rivers flowing through densely populated regions generally have sands with large amounts of organic matter.

The Bureau of Standards[2] considers organic matter, sulphides, and soluble alkalies in sands as highly objectionable. On pages 10–11 tests are given for the determination of organic matter in sand, and these tests have been made on most Georgia sands. In general, Georgia sands are quite free from harmful organic content.

MINERAL AND CHEMICAL IMPURITIES

Under mineral impurities mineral grains of less resistance than quartz might be included. Feldspar, which occurs in many Georgia sands particularly those in the Piedmont region, although it is subject to disintegration into kaolin, or clay, is usually sufficiently durable when it occurs in sands to cause no trouble in mortar. Hornblende is still less common in sand, due to its weaker resistance to abrasion. Quantities exceeding 5 to 10 per cent of either mineral in sand might produce weakness due to disintegration under the pressure caused when the cement sets. The writer knows of no experiments that have been made to determine the effect of different amounts of feldspar or hornblende on concrete sand.

In the case of mica, however, Willis[3] found that the addition of 2½ per cent of finely ground mica to Ottawa sand reduced the strength of the mortar at 28 days about 33 per cent, and also increased the per cent of voids in the sand. This decrease in strength may have been due largely to the increased voids in the sand.

---

1 Gaines, R. H., Am. Soc. for Test. Mat. Proc. Vol. II, p. 522, 1911.
2 Circular No. 45, pp. 35-36, 1913.
3 Willis, W. N., Cement Age, p. 172, March, 1907.

Particles of schist, gneiss, slate, and shale are common in the small stream sands of North Georgia. Due to the fissility of the schist, gneiss and slate, and the softness of the shale, these substances should be guarded against, and sand containing over 20 to 25 per cent of such material should be rejected even for small operations.

Pebbles of the coarse aggregate should be hard and resistant. The character and properties of weak pebbles in a gravel mass can readily be found by breaking some of the pebbles with a hammer. (See page 78). Pebbles of sandstone and shale likely to disintegrate to sand and clay during the mixing or settling of concrete, are undesirable in aggregate gravels. Schist pebbles are also weak, and gravel containing many of them should not be used. Some of the Georgia gravels contain pebbles of originally hard material that has rotted during long exposure and now has very little resistance.

Aiken[1] suggests that a concrete sand should contain 95 per cent silica at least. He found that of two sands having the same granulometric content, that with the higher silica content produced much stronger cement than that whose silica content was less. Sands with over 90 per cent silica tested approximately 25 per cent stronger than sands whose silica was under 80 per cent.

Although the silica factor is worthy of noting in a few sands which manifestly contain a large percentage of minerals other than quartz, it is hardly worth while to include it in specifications, since the great majority of sands rarely owe what difficiencies they possess to their lack of silica.

Calcareous sands.—Calcite or limestone grains do not appear to injure a concrete sand. Coral sand has been successfully used where[2] no other kind was available. Limestone screenings are ferquently used as the fine aggregate in concrete, and tests have shown as much as 50 to 100 per cent strength increase over silica sands of the same granulometric composition.[3]

Sea-sand.—Due to the coating of salt which the grains of sea-sand usually possess, it is not advisable to use it for mortar. The salt is deliquescent and a wall or structure made from such sand will

---

1 Aiken, W. A., A sand specification and its specific application: Am. Soc. for Test. Mat. Proc., Vol. 1, pp. 341-348, 1910.
2 Webb, D. C., Tests of coral sand and rock with reference to their use in concrete: Eng. News, Vol. 59, p. 524, 1907.
3 Taylor, F. W. and Thompson, S. E., op. cit., p. 166.

always be damp, unless the sand is exposed to the weather, away from salt water, for several weeks before using.

BRICK MORTAR

According to Condra[1] sand for brick mortar should pass a 10-mesh screen and 80 per cent of it should be coarser than an 80-mesh sieve. Mortar in brick and masonry work is subjected to compressive strains, particularly if used in tall buildings, and the grains should preferably be all as coarse as the thickness of the joint will permit, since mortars made from the coarsest sands are the strongest. Sand whose grains are mostly between 6 and 20 mesh in size are probably the best for brick mortar. Good grading is secondary, as far as strength goes, but it reduces the amount of cement required.

Cleanness.—Small amounts of clay, if evenly distributed through the sand, are not harmful, but they are to be avoided if they occur coating the sand grains. Organic matter is to be guarded against, particularly if it coats the grains. Particles of lignite and similar materials are undesirable, especially if they occur on the outer surface of the mortar in the wall, since they cause unsightly marks.

Color.—Color is usually not an important quality, except in fine work when a sand is desired to match the color of the brick as nearly as possible. Round-grained sands are, in practise, as effective as sharp-grained sands.

STONE MASONRY MORTAR

The characteristics of sand for stone masonry work are practically similar to those for brick work, except that in rough stone work the joints are thicker and a coarser sand may be used. In fine work, such as that connected with dimensioned blocks in buildings and monuments where the joints are made as thin as possible, a very fine-grained sand is generally used, corresponding in color to that of the stone. Organic matter in fine stone work is to be avoided, particularly particles of lignite.

PLASTER

Plaster is a mixture of sand and some other material depending on the finish required on the surface to which it is applied. The plas-

1 Condra, G. E., The sand and gravel resources and industries of Nebraska: Nebraska Geol. Survey, Vol. 3, pt. 1, p. 150, 1908.

ter may be made from gypsum, (plaster of Paris), lime, or cement. The sand used in plaster should be clean, even-grained, and as coarse as the thickness of the plaster coat will permit.

Cleanness.—Clay disseminated throughout the sand if in small quantities is not particularly harmful, but it should not coat the grains. Plaster used in lining reservoirs or in places requiring water tightness may contain as much as 10 per cent of clay, which is believed to make it more impervious to water.[1]

Organic matter in all amounts is to be avoided. Lignite or peat in the sand is very injurious, since it expands on drying, and if on or near the surface, it will cause the plaster to pop and leave unsightly pits. Georgia sands have very little lignite.

Grain size.—Sand for plaster may be as thick as the coating, but usually it should pass a 10-mesh sieve. Much fine material is harmful, since it causes the plaster not to "clinch" well behind the lathe, but to "fall through."[2] Factors such as grading and coarseness of grain, that are essential for strong mortar and concrete, are not so important in plaster sands, since strength is not of major importance.

Color.—Except in finishing coats color is not important. Outside coats usually require a light-colored sand and where extreme whiteness is desired a pure white sand is used.

The sand from the Crawford and Talbot county regions is excellently suited for plaster and mortar work, as are most of the South Georgia sands, unless the clay admixture becomes too great. The coarser river sands, particularly the creek sands of the Piedmont region, are sometimes too coarse for plaster and mortar work.

GLASS SAND

Sand composes from 52 to 70 per cent of the bulk of the mixture of raw, glass-making materials, and upon it depends the transparency, lustre, and hardness of the glass. A careful consideration of its qualities is, therefore, extremely important. Although purity and grading of the sand is essential, it is only rarely that these qualities are

1 Taylor, F. W., and Thompson, S. E., Concrete, plain and reinforced, 2d ed., p. 343, 1911.
2 Dake, C. L., Sand and gravel resources of Missouri: Missouri Bur. Geol. and Mines, Vol. XV, 2d ser., p. 52, 1918.

ideally developed in the natural product. It is interesting to note that generally throughout the world, the purest sands, from the standpoint of silica content, are found in the later geological formations. This is due to the longer period during which the quartz grains have been reworked by water many times and their impurities carried off. Both unconsolidated sand and cemented sand, or sandstone, are used in glass manufacture. When sandstone is used crushing is necessary, and consequently a fairly friable stone which breaks down easily between the grains, rather than across the grains, is desirable.

Frequent attempts have been made to use ground quartz in the manufacture of glass, but they have invariably been failures[1] due to the great cost of crushing the tough quartz to the requisite fineness.

CHEMICAL COMPOSITION

The chemical analysis of a glass sand should show the percentages of silica (SiO_2), iron (Fe_2O_3), alumina (Al_2O_3), and the loss on ignition, (water and organic matter).

Silica.—Boswell[2] says the silica percentage should be preferably over 98 per cent, although for common bottle glass the percentage may drop as low as 95 per cent and in the best optical glass at least 99.5 per cent silica should be in the sand. Some Illinois and Pennsylvania sands attain a content of 99.9 per cent silica. In 600 analyses of 210 different glass sands cited by R. L. Frink,[2] the highest silica content was 99.71 and the lowest 88.51, but it is said that the latter made better glass than the former, due to alumina in the sand.

Iron.—Iron, either in the form of the oxides, limonite or magnetite, or in other minerals, is particularly undesirable in glass sands, since it gives the glass a green or yellow color. Much more laxity has been allowed in the past few years in setting the iron content limits than formerly, since it has been found that for most purposes just as good glass can be made with a somewhat higher content. Although a glass sand, comparatively free from iron, is generally snow-white, the color of a sand alone is not an indication of its purity, since minute particles of magnetite or ilmentite may occur through the sand and be almost invisible, yet they will sometimes give the sand an iron content of as much as one per cent.

1 Mining & Scientific Press, Oct. 16, 1915, pp. 599-600.
2 Some fallacies and facts pertaining to glass-making :Am. Ceramic Soc. Trans., Vol. II, pp. 296-317, 1909.

For the best flint and optical glass Boswell[1] believes the iron, as Fe_2O_3, should not exceed 0.05 per cent, but for window and plate glass, 0.1, 0.2, and even 0.3 per cent are permissible. Burchard[2] considers 0.2 per cent Fe_2O_3 as the limit for sand used in plate glass manufacture.

Buttram[3] gives 0.3 to 0.4 per cent as permissible percentages in plate glass when decolorizing agents are used and calls attention to some grades of English plate and window glass containing as much as 1.92 per cent iron. French mechanically pressed plate glass averages 0.14 per cent iron. The same authority speaks of lead glass containing up to 1.93 per cent iron and 5 per cent iron in some lime glass, with the better grades of bottle glass averaging 0.65 per cent.

The Pittsburgh Plate Glass Company[4] considers the iron limit for plate glass as 0.1 per cent, but prefers 0.05 per cent. For white bottles the iron content should not much exceed 0.5 per cent, but for other bottles the iron content may range from 0.5 per cent to 7 per cent.

Alumina.—Alumina in glass for use in refractory work is desirable, since it makes a glass that stands melting without change[5]. Alumina in the form of clay is generally thought to be highly undesirable, since it clouds the glass. Buttram[6] gives 0.1 per cent Al_2O_3 as the limit in sands for the manufacture of high grade flint ware, while up to 0.6 to 0.7 per cent alumina occurs in many sands for window and plate glass manufacture. In bottle glass 2.2 per cent is about the average.

Frink[7] believes that alumina is bad for optical glass, but that for most other glass, alumina is not harmful. He cites cases in which excellent glass was made from a sand containing 6 per cent and thinks even as much as 10 per cent not prohibitive. The alumina aids the annealing of the glass, reduces the coefficient of expansion, and prevents, to a large extent, the formation of cords or strings, making the glass more homogeneous. On the other hand alumina decreases

---

1 Boswell, P. G. H., Memoir on British resources of sands suitable for glass-making with notes on certain crushed rocks and refractory materials, 1916.
2 Burchard, E. F., Glass sand, other sand, and gravel: U. S. Geol. Survey Mineral Resources, 1911, pt. 2, p. 594, 1912.
3 Buttram, Frank, The glass sands of Oklahoma: Oklahoma Geol. Survey, Bull. 10, p. 11, 1913.
4 Dake, C. L., op. cit., p. 83.
5 Havestodt, Jena glass, translated by J. D. and A. Everett, Munn & Co. London, p. 21 .
6 Buttram, op. cit., p. 11.
7 Frink, R. L., Effects of alumina on glass: Am. Ceramic Soc. Trans., Vol. XV, p. 296, 1909.

the fusibility of glass, and increases the viscosity where it occurs in amounts over 3 per cent. On the whole, then, for most grades of glass, alumina in small amounts may be considered beneficial rather than harmful.

Magnesia.—Formerly 0.2 to 0.4 per cent magnesia was believed the limit in the batch, but Frink[1] mentions a plant producing good glass and using 6 to 9 per cent of magnesia in the limestone alone. He believes, however, the total magnesia in sand and limestone should not exceed 6 per cent.

Analyses of high-grade glass sand

Constituents	*1*	*2*	*3*	*4*	*5*	*6*
Silica (SiO_2)	99.85	99.22	99.89	99.34	99.88	99.80
Alumina (Al_2O_3)	.14	.32	.105	.297	.18	.13
Iron oxide (Fe_2O_3)	.012	.14	.005	.043	.02	.006
Lime and magnesia (CaO & MgO)	trace	.18	trace	.15	--------	trace
Total	100.002	99.86	100.00	99.830	100.08	99.936

1.—Oriskany sandstone, Mapleton, Pa.
2.—Burgen sandstone, Talbequah, Okla.
3.—Oriskany sandstone, Berkely, W. Va.
4.—Dakota sandstone, Perry County, Mo.
5.—Best Lippe sand, Saxony.
6.—Fontainbleau sand, near Paris, France.

As a rule, sands whose chemical composition conforms to the silica, iron, and alumina limits, will not show more than a trace of lime, magnesia, titania, and the alkalies. A high alumina content frequently means a high titania content. The effect of titania, although injurious, is little known. Water, since it causes air bubbles and organic matter due to its reducing qualities, are both objectionable where a high grade of glass is desired.

MINERAL COMPOSITION

In view of the fact that quartz is pure SiO_2, a sand that is almost entirely composed of quartz grains will most likely be free from

1 Frink, R.L., Some fallacies and facts pertaining to glass-making: Am. Ceramic Soc. Trans., Vol. XI, pp. 296-317, 1905.

impurities. The heavier and darker minerals such as magnetite, hornblende, leucoxene, titanite, and ilmenite, are undesirable, since such minerals often contribute largely to the iron content of a sand. Their elimination, therefore, will greatly improve a sand. Examination of a sand mineralogically also serves as a check on its character and on the deposit from which the sand came, since usually glass sands are uniform in their mineral content, and any change noted will indicate a change in source, or the introduction of some impurity in transit.

A mineral examination of sand is readily made with a pocket magnifying glass. If some of the sand is placed in a drop of clove oil under a microscope, the fine quartz, since its index of refraction is about the same as that of clove oil, will stand out in relief. Any coating, likely to account for a high iron content, can be observed in this way, since such coating cause otherwise pure quartz to be visible through the oil.

MECHANICAL COMPOSITION

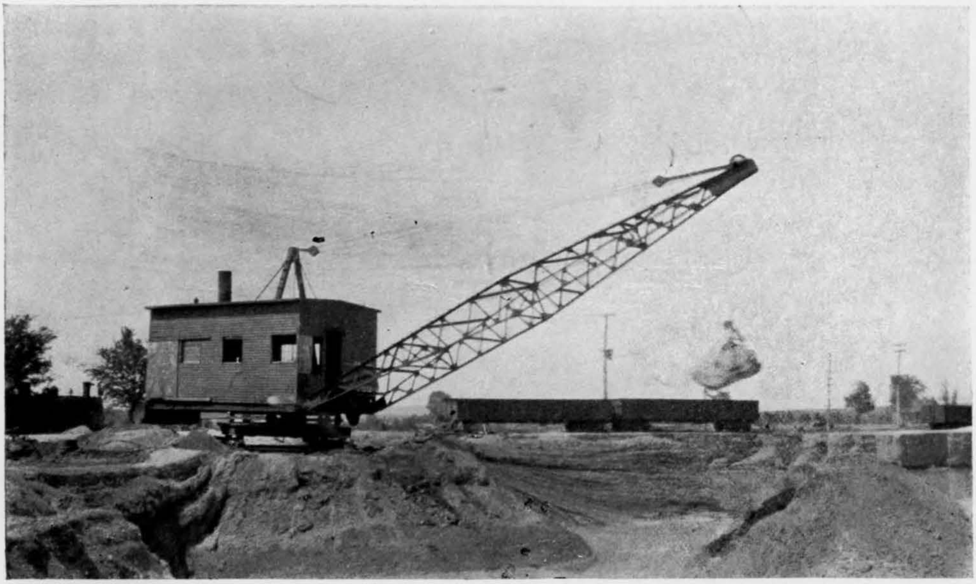
Some glass makers who have studied their sand in great detail put the question of grain size on a par with that of chemical composition. Grading is indeed a most important factor as numerous mechanical analyses have shown, yet few glass makers give it much attention.

Boswell[1] thinks a batch should have at least 70 per cent of the sand of one grade, preferably from ¼ to ½ mm. in diameter (30 to 55 mesh). Coarse grains are left unmelted as stones in the molten batch. Fine material such as silt and clay is particularly undesirable, since it clouds the glass and permits the inclusion of air which causes bubbles. Fine material also melts first and sinking to the bottom causes layers of uneven density, which later produces "wavy" or "cordy" glass when blown.

Burchard[2] considers that the sand should be of medium fineness passing a 20 to 50-mesh screen, and that sand uniformly finer than one sixtieth of an inch is said to burn out. Boswell, however, says that sand of this latter size will not burn out. In general, finer sand is used by British glass-makers than by American glass-makers.

Kümmel and Gage[3] say "If the majority of the grains have a dia-

1 Op. cit.
2 Op. cit., p. 595.
3 Kummel, H. B. and Gage, R. B., The glass sand industry of New Jersey: New Jersey Geol. Survey, Ann. Rept. for 1906, pp. 77-96, 1907.



A. MINING GRAVEL BY CRANE DRAG-LINE SYSTEM, RICHMOND COUNTY GRAVEL PIT, AUGUSTA

B. MINING SAND BY TRAVELLING DERRICK AND CLAM-SHELL BUCKET, SMILEY SAND COMPANY, NEAR GAILLARD, CRAWFORD COUNTY meter less than 0.136 millimeter (passing a sieve having 120 meshes per linear inch) the sand is said to 'burn out' in the batch and will not produce as much glass per unit as when composed of coarser grains. When the grains are uniformly larger than 0.64 millimeter (30 mesh) in diameter more time is required to fuse them than otherwise. This lowers the amount of sand each furnace can melt per day and increases the cost of the glass produced."

Similar limits for the size of the grain are given by Buttram.[1] The following mechanical analyses of typical glass sands from various sources are given:[2]

Mechanical analyses of glass sands

Operator	Locality	Color	Percentages passing			
			20 mesh	40 mesh	60 mesh	100 mesh
Ottawa Silica Co.	Ottawa, Ill.	White	99	85	18	3
E. J. Reynolds & Co.	Utica, Ill.	Grayish yellow	99	45	11	3
Tavern Rock Sand Co.	Klondike, Mo.	Faint pinkish yellow	100	82	17	2
Pacific Glass Sand Co. Direct from quarry	Pacific, Mo.	Faint yellow	100	96	46	2
West Virginia Sand Company Finish product	Berkeley Springs, W. Va.	Grayish White	100	98	25	1

SHAPE OF GRAIN

A sharp grain, since its edges fuse more readily, is generally believed more desirable. Many plants in the Mississippi Valley region and in other parts of the United States are producing all grades of glass, including the best flint ware, from sand of rounded grains.[3] Whatever effect the shape of the sand grains may have upon the melting of the batch, or upon the glass, it is probably too insignificant to be worthy of consideration.

1 Op. cit., pp. 16-17.
2 Burchard, E. F., op. cit., p. 626.
3 Burchard, E. F., op. cit., p. 595.

METHODS OF IMPROVEMENT

Very often, sand, apparently unsuited for the manufacture of glass, may be ridden of its impurities, by simple and comparatively inexpensive treatment. Sands used for making inferior grades of bottle glass can sometimes be improved in this way, so that they can be employed in the manufacture of better glass and so increase their value.

Washing.—As a means of removing the clay, with its iron and alumina content, washing has been most frequently resorted to, and it is surprising how many apparently worthless sands can be made suitable for glass by washing. The following table shows the result of washing a sand (No. 1) from near Blackshear, Georgia (see page 228), the average analysis (No. 2) of a large number of sands made by the Pittsburgh Plate Glass Company,[1] and the analysis of a slime from a washed Ottawa sand.

Analyses of washed and unwashed glass sands and slime

Constituents	Unwashed		Washed		Slime
	1	2	1	2	
Silica (SiO_2)	95.20	99.405	99.49	.782	87.21
Ferric oxide (Fe_2O_3)	2.11	.075	.31	.031	7.50
Alumina (Al_2O_3)	1.16	.210	.05	.049	.52
Alkalies	----------	----------	----------	----------	.20
Loss on ignition	.76	.170	.04	.100	----------

Sometimes the improvement of the iron content by washing is too small to warrant the expense, in view of the corresponding loss in alumina, which, as previously pointed out, is a desirable constituent of the sand.

Washing not only removes a large part of the iron content, but it also removes, even from high-grade sands, considerable finely divided

1 Dake, C. L., Sand and gravel resources of Missouri: Missouri Bur. Geol. and Mines, Vol. XV, p.42, 1918.

silica, which may be injurious, as well as organic matter and other impurities whose detrimental action it is desirable to reduce. If the iron occurs in the sand as magnetite, ilmenite, or similar minerals, which occur in small grains; or if the quartz grains are coated with a persistent film of limonite, washing will not materially improve the sand.

Washing is extensively employed in Illinois, West Virginia, Pennsylvania, and to a lesser extent, in Indiana, Ohio, and Missouri. The methods are briefly described under Preparation of Sand for the Market. (Page 120.)

Magnetic treatment.—Since magnetite and ilmenite, which frequently are a source of iron in glass sand, are magnetic, the possibility of removing these minerals by the use of electromagnets is suggested, as well as particles of iron abraded from the crushing machinery by the hard quartz grains. At least one[1] glass maker uses this method to improve his sand.

Screening.—Kümmel and Gage[2] have made experiments showing that minerals such as magnetite, titanite, ilmenite, and leucoxene, which are highly ferruginous, generally occur in sand as grains which pass an 80-mesh screen. Their suggestion, of screening out the grains passing 80 mesh, before marketing, is an excellent one, and should be investigated by producers wishing to increase the value of their sand, although it is likely that with the present methods of screening, considerable difficulty will be encountered in doing this economically. Not all sands, however, owe their iron content to these fine-grained black minerals. Many Georgia sands, as they occur in the pit are barred from use in glass-making by their limonite content, rather than their magnetite content.

---

1 Fettke, C. R., Glass manufacture and the glass sand industry of Pennsylvania: Pennsylvania Top. and Geol. Survey Comm., Rept., XII, p. 64, 1919.
2 Op. cit., p. 92.

Table showing improvement effected by screening out sand passing 80 mesh

Constituents	Sample 669 A		Sample 672 A	
	Before screening	After screening	Before screening	After screening
Iron oxide (Fe_2O_3)	0.0068	0.0022	0.0114	0.0029
Titania (TiO_2)	0.117	0.024	0.234	0.0434
Alumina (Al_2O_3)	0.276	0.085	0.366	0.106

PREPARATION OF GLASS SAND

In West Virginia, Pennsylvania, Missouri, Kansas, and Oklahoma, most of the glass sand produced is from sandstone. This must, of course, be quarried or mined, crushed, screened, washed, drained, dried, and finally screened into the desired sizes. If the sandstone is friable, hydraulic quarrying is generally employed but usually the use of some dynamite is necessary to loosen the harder ledges. Fairly pure sandstone is found in Walker County on Rocky Face this state and an attempt was made in 1915 to work it.

Glass sand obtained from the Coastal Plain area of Georgia is unconsolidated and may be recovered by hand or power shovels, loaders, or centrifugal pumps. In many places the overburden is so unsuited for glass purposes that it is necessary to keep it and the glass sand apart, so that hand recovery has been found more satisfactory than mechanical means.

The various methods of mining, washing, screening and other treatments are described elsewhere in the report.

FOUNDRY SAND[1]

The term foundry sand includes molding sand, which is generally fine-grained and contains a clay bond, and core sand, which is coarser-

1 For details regarding molding sand see, Ries, Heinrich and Rosen, J. A., Michigan Geol. Survey, 9th Ann. Rept., pp. 33-85, 1908.
Kummel, H. B. and Hamilton, S. H., New Jersey Geol. Survey, Ann. Rept. for 1904, pp. 189-243, 1905.

grained, and usually requires the addition of an artificial bond. Molding sand is used to construct the forms into which the molten metal is poured, and the core sand is used to fill up the hollow spaces in the cast. The demand for molding sand in Georgia is supplied almost entirely from within the state. Small amounts are also shipped to markets outside the state. Molding sand is mined near Almon in Monroe County along Yellow River; at Ringgold in Catoosa County along Chickamauga Creek; and just north of Dalton in Walker County. In 1919 the production of molding and core sand in Georgia was 64,491 tons, having a value of $33,883.

The many different kinds of metals cast and the differences in the manner of casting require molding sand with exacting and sometimes indefinable characteristics. Foundrymen are frequently prone to reject a local sand in favor of one that must be transported long distances, sometimes across the continent, or from Europe, but which is believed to have qualities that can not be found elsewhere. In selecting a molding sand, unbiased judgment of it from its results will often save a foundryman considerable money in freight charges. The determination of the value of a molding sand is a much harder matter than of sand used for other purposes. The practical foundryman usually squeezes some of the sand in his hand to test its power of retaining a form, or he will blow through it to determine its venting power or permeability. Numerous laboratory tests have been devised, but it is not likely that any of them will give an exact idea of the performance of the sand in practice. They serve rather for comparative purposes, and to eliminate sands from further consideration. Actual testing with the molten metal in the foundry is the only reliable way to find out what a sand can do. The sand as it comes from the pit is rarely exclusively used in foundries, but is added little by little to an old sand already in use, to replace the burnt-out grains that have been previously removed by screening. At best, then, laboratory tests are really only comparative.

The essential qualities of molding sand are permeability, texture, cohesiveness, durability, and refractoriness.

Permeability.—The ready escape of gases from the molten metal through the sand mold is essential to proper founding. If the gases cannot escape, "scabs" or blow holes will be formed on the surface of the casting. The facility with which the gases escape depends on the shape and size of the pore passages in the sand, and the extent to which these openings are maintained after the metal is poured. Porosity, therefore, is not an indication of the permeability, or venting power, of a sand. A large porosity caused by numerous minute passages does not necessarily mean that the sand is permeable; on the other hand, a small porosity, if induced by a small number of larger passages, will produce a highly permeable sand. Permeability is rather a function of the texture. Small castings do not require a sand of as high a permeability as larger castings where more steam and gases are produced. The amount of water added to temper the sand, or bring out its cohesiveness, is often too great, and the permeability of the sand is thereby decreased. Just enough water should be added to lubricate the grains. Methods of testing the permeability of a sand are described on pages 24-25.

Texture.—Maximum permeability in a sand of given fineness is usually attained when the component sand grains are rounded and of equal size. Upon the texture of the sand depends the smoothness of the face of the casting. For heavy iron castings a coarse sand can be used; but for stove-plate work, brass, and aluminium, the sand should be fine-grained, and have a high degree of permeability as well. The size of the grain, therefore, largely determines the grade of the sand. The texture can be found either by the use of sieves, or by elutriation and aspiration methods described on page 24.

Cohesiveness.—Cohesiveness, or bonding power of a molding sand, refers to its property of retaining a shape when slightly moist. This quality is probably the most important molding sand can possess. It is due, in part, to clay in the sand, and also depends, somewhat, on the fineness of the sand and the sharpness of the grains. It is not so much the amount of clay in a sand that increases its cohesiveness but rather the "fatness", or plasticity, of the clay. The least possible amount of clay in a molding sand is best. Neither a chemical nor mechanical analysis serves as an index to the cohesiveness.

Richard Moldenke[1] considers a sand having 20 per cent of plastic clay to be the most desirable. He gives the results of the rational analyses of a number of molding sands as follows:

1 The molding sand problem is important: Iron Age, Vol. 94, pt. 1, pp. 544-546, 1914.

Average rational analyses of molding sands

Constituents	Average per cent	Maximum per cent	Minimum per cent
Quartz	65.53	68.7	45.6
Clay	21.73	41.2	8.9
Feldspar	12.74	32.4	2.3

The general method of testing a sand for its cohesiveness used by the Bureau of Standards, is to mix 500 grams of the sand with a definite quantity of water and mold some of it in a snap flask on a piece of plate glass. The dimensions of the flask should be 1 x 12 inches and the sand should be tamped firmly in with the thumb and forefinger. The plate and bar of sand are then weighed, and the bar is slowly pushed over the edge of the glass plate until the weight of the unsupported end is sufficient to cause the bar to break. The fragment remaining on the plate is then measured, and the data used in the following formula:

$$S = \frac{\text{Wt. of bar (in grams)}}{4} \times \frac{L^2}{45.6}, \text{ in which}$$

S = transverse strength.
L = length of overhang in inches.

Average tests of samples are made with increasing quantities of water until the bar is deformed when pushed.

Durability.—After a molding sand has been used a number of times, depending on its quality, the continual action of great heat causes the clay to become de-hydrated and the grains to fuse slightly causing two or more to stick together and form lumps. The cohesiveness is reduced and the sand is said to be "dead", or burnt out. To improve it, the burnt out or coarse particles are screened out, and new, or "green" sand, is added. The only way to judge the durability of a sand is to actually use it in commercial foundries until it is burnt out.

Fusibility.—The fusibility or refractoriness of a sand is the measure of the amount of heat a sand will stand without fusing. If the grains forming the inner surface of the mold fuse even slightly, escape of the gases will be difficult or impossible, and scabs will form on the casting. Sands used in iron and brass work are not so likely to fuse, since the heat is not so great and a silica percentage of 70 or 80 is sufficient except in very large castings. For steel castings sands should contain at least 96 per cent of silica, and a little clay. The fluxing materials in molding sands are lime, magnesia, iron oxide and the alkalies. The finer-grained portion of the sand is likely to be richest in fluxes. To test for fusibility a cone 2½ inches high by ⅝ inches wide at the base is made of the moistened sand. The sand is subjected to great heat with standard seger cones and the melting temperature determined.

Substitutes for molding sand.—Satisfactory molding sand has been prepared[1] by crushing a friable sandstone; decayed granite; or shattered sandstone, whose fractures are filled with a plastic clay. Earthy loams are also washed to remove part of the clay and used for molding. Clay has also been added to pure quartz sand to produce molding sands. The adoption of such methods will assure an adequate supply of sand, even though the natural deposits should be exhausted, and also a uniform sand for each requirement.

CORE SANDS

To form molds for the cores or interior spaces of castings, core sands are used. To such sand, artificial binders are added, which will be destroyed by the heat of the metal and cause the sand mold to fall apart and be easily removed when the casting has cooled. Core sands are, therefore, generally a fine-to medium-grained sand of uniform size, thus insuring the maximum venting. Unless the surface of the mold is protected with a coating of silica wash, the sand should be fine enough to prevent penetration of the molten metal. The following mechanical analysis is of a sand from near Howard, which is used largely in core work.

1 Cole, L. H., Summary rept. for 1916, Canada Dept. Mines, Mines Branch, 1917.

Mechanical analysis of a washed core sand, Howard, Georgia, (T-83)

Percentages retained on following screen sizes											
8	10	14	20	28	35	48	65	100	150	200	200
.1	.5	1.7	5.0	12.3	21.0	20.8	19.9	13.0	4.2	1.3	.2

In large iron cores a coarse sand with a clay bond can be used; but in smaller castings an artificial bond such as molasses-water, flour, starch, or dextrine, is added. Core sands for steel castings should not contain more than 3 per cent of material other than silica (fluxes), so that the heat of the molten steel will not fuse the sand.

Large quantities of core sand are shipped from the Talbot and Crawford County pits to Atlanta and Birmingham foundries.

SAND LIME BRICK

Although sand-lime brick as known to-day, has been developed within the last 25 years, they were made by the ancient Egyptians and Babylonians. Examples of their product have often been found, and they appear to have well withstood the ravages of time.

In brief the manufacture of sand-lime brick consists in mixing sand and lime moist; molding under pressure; and hardening by steam, forming a chemical bond of calcium silicate.

The industry was first developed in Germany and at present hundreds of plants exist in England and France. In the United States the growth has been more recent, dating from 1902, although today there are a great many plants manufacturing sand-lime products, particularly in Michigan, New York, California, and Indiana. The Tift Silica Brick Company, located about 1½ miles from Albany, east of Flint River, is the only sand-lime brick plant operating in Georgia.

Sand requirements.—A comparatively pure quartz sand or granular silicate (quartzite or sandstone), with a quartz sand most in favor, all of whose grains pass 20 mesh, is desirable. The sand should have at least 80 per cent of silica, consequently the ordinary silicate impurities in sand are not a detriment. More than 4 to 5 per cent of clay will cause the product to disintegrate easily under the influence of the weather; the sand should preferably have not more than 2 per cent of clay.[1] Peppel[2] made a number of experiments to determine the effect of clay on the sand and concluded that clay up to 10 or 12 per cent was not injurious and that possibly as small an amount as 2½ per cent might be desirable. Feldspar which usually occurs in sand, will decrease the crushing strength and increase the tensile strength, if more than 10 per cent is present.

The grains of sand should be preferably of various sizes. If the sand is all fine, the amount of soluble silica is increased. A large amount of fines will prevent air and gases from escaping when the brick is put into the steam cylinder, and cracks will result; but some fines are necessary to fill in the spaces about the coarse grains, and to aid in the formation of a strong bond. As a rule[3] the more fine sand (80 to 150 mesh) in a brick the less the crushing strength, but the greater the tensile strength. The best sand for sand-lime brick should have most of its grains between 60 and 100 mesh. Peppel[4] believes with a sand whose grains are all retained on a 40-mesh sieve, one fourth should be pulverized so that one eighth of the total sand will pass 150 mesh. The grains should be sharp and free from alkalies.[5]

The lime.—The lime tests[6] have shown a high calcium lime to be more desirable than a magnesian lime since calcium silicate is the stronger bond. Usually from 5 to 10 per cent of lime is used, depending upon the quantity of silica in the sand. Peppel[7] found that although the strength of the brick increased with the addition of lime, the strength gained by its addition above 10 per cent did not warrant the increased expense. Parr and Ernest[8] found that too much lime weakens the bond and increases the absorption.

METHODS OF MANUFACTURE

There have been developed a number of ways of treating the sand and lime and making it up into the resultant brick. The general principles are equally applicable to all of these methods and these will be considered here.

1 Parr, S. W. and Earnest, T. R., A study of sand-lime brick, Illinois Geol. Survey, Bull. 18, 1912.
2 Peppel, S. V., The manufacture of artificial sandstone or sand-lime brick: Ohio Geol. Sur. Bull. 15, 4th ser., 1906.
3 Parr, S. W. and Earnest, T. R., op. cit.
4 Peppel, S. V., op. cit.
5 Coons, A. T., U. S. Geol. Survey Mineral Resources, 1900, p. 1154, 1905.
6 Peppel, S. V., op. cit.
7 Peppel, S. V., op. cit. p. 36.
8 Parr, S. W., and Earnest, T. R., op. cit.

The sand is first screened to remove twigs, leaves, and pebbles, and then it should be thoroughly dried. The value of drying is sometimes underestimated. It aids in grinding the sand and permits of a more accurate proportioning of the water added to the mixture. Part of the sand, ranging from one-fourth to two-thirds, is put through a large tube mill, with silex lining, and using silex or chert pebbles, similar to those in use in a cement plant. Here the grains larger than 20 mesh are reduced; the dry granulated lime and the coloring matter, if any, is added. The rest of the sand is then added and the whole mixture passes dry to a pug mill, where the necessary water for slacking is added. This method is known as the quick-lime process and is the most general and desirable method in use. From here the wet mixture passes to one compartment of a large cylindrical silo where it remains for 24 hours, permitting each sand grain to become coated with lime. The two compartments of the silo permit use from it on alternate days.

From the silo, the material which is now in a moist, warm condition, passes to circular presses after the addition of a small amount of water where about 100 tons pressure is applied to each brick. The molded bricks are then placed in long steel tubes, called hardening cylinders, ranging from 50 to 80 feet in length, where steam pressure of from 110 to 175 pounds is later turned on and maintained for 8 to 14 hours. The usual practice is to maintain the 120-pound pressure for 8 hours. After removal from the cylinder, the bricks are ready for use, but they gain in strength for 8 to 10 months after pressing.

The natural color is pale ivory often tinted with pink or yellow. By the addition of mineral pigments or lamp black, almost any desired color may be produced.

Several variations of the method of mixing the sand and lime are in use and are described by Peppel.[1] In the *wet slacking* process, the lime is slacked to a fat putty and then mixed with the sand and water in a wet pan or pug mill. The *dry slacking* process differs little from the wet slacking method except that the lime is slacked with just enough water so that the heat generated will dry the finished hydrate. In the *acid slacking* method 5 to 10 per cent of a hydrochloric acid solution is added to the lime after slacking has begun. The acid is said to hasten slacking and shorten the time for hardening in the steam cylinder.

1 Peppel, S. V., op. cit., pp. 19-22.

Character of brick.—The sand-lime brick makes a beautiful, neat, and exceedingly durable building material, either for residences, large office buildings, or factories, and its strength compares very favorably with that of clay bricks.

ROAD GRAVEL

In 1914, 42 per cent of the surfaced roads of the United States were constructed of gravel. A gravel road is similar in many ways to a sand-clay road except that a coarser sand or gravel is used. The requirements of an effective binder; good grading; and contact of the coarser particles, thus insuring a minimum of the less resistant binder, apply with equal force to the gravel as to the sand in sand-clay roads. (Page 81).

Although there are few gravel roads in Georgia as a whole, due to the frequent remoteness of the deposits, excellent examples may be seen in the vicinities of Savannah, Augusta, Macon, and Columbus. On account of the freight costs gravel can rarely be hauled more than 100 miles by rail. Although some gravel is brought to Georgia points from the Montgomery district in Alabama, and considerable South Carolina gravel is used in Chatham and a few adjoining counties, most of the road gravel used in the state must be obtained locally. Very often such deposits present little choice. Nevertheless, it is quite necessary that those in charge of road construction be familiar with the proper qualities of good Georgia road gravel and that they select the best possible gravel where a choice is afforded.

The three requisites of a good road gravel are:

1. An effective binder
2. Resistant pebbles or rock fragments
3. Well graded pebbles

The Binder.—The following extract from Bulletin 2 of the Michigan State Highway Department is of value in emphasizing the desirable features of the binder:

"Authorities have differed as to the requirements of suitable road gravels, most of them, in my opinion, placing too much stress on the immediate packing qualities. Indeed, the average township commissioner and farmers generally have become so imbued with the idea that it is necessary to use a gravel that will pack quickly that they have almost lost sight of the fact that the only thing which makes a gravel road better than an earth road is the pebbles, real stones, that it contains and is dependent upon to bear up traffic and resist wear.

"The most common material sought after for the binder in gravel roads is clay. But, considering all kinds of weather, it is probably the poorest cementing material we have. If present, much in excess of 10 per cent of the mass, it will make mud whenever there is a prolonged wet spell, and especially when frost is coming out of the ground in the spring. Ideal clay gravels contain only enough clay to coat the pebbles, with no free lumps. Such gravels are excellent for the first layer on sandy soils, but sand gravels are much better for the first layer on clay and loamy soils.

"Gravels that come from the pit with the pebbles cemented together, even though they contain no clay, will recement in the road and become harder than they were in the pit. Tests of specimens of this kind always show that there is much lime present and usually some iron, both of which are excellent cementing materials. Briefly, the experience of the State highway department warrants the statement that there are few, if any, bank gravels in Michigan that do not contain enough limestone and other soft pebbles, which grind up under traffic, to furnish sufficient binder to cause them to consolidate in a few months' time, if separated from the surplus sand and earth, and properly treated after applying to the road.

"In accordance with these suggestions, gravels are considered valuable for road purposes in the following order:

(1) Almost in direct proportion to the percentage of pebbles constituting the mass.

(2) In direct proportion to the value as road metal of the rock fragments constituting the pebbles.

(3) In direct proportion to the value as a cementing material under all conditions of weather, of the finer particles of earthy matter constituting the filler or binder."

Due to the low cementing value of so many gravels used in road building, the question of binder is considered by some of more importance even than that of the durability of the pebbles. Observation of the natural bank or face of a gravel deposit is an excellent guide to the cementing qualities of the binder. Where the face stands vertical, requiring loosening by shovels, with large lumps of cemented pebbles at the base, the binder is probably very effective. Gravel from the vicinity of Augusta, Georgia, and across Savannah River in South Carolina, is noted for its high cementing qualities, which are due to a kaolinite binder making up 10 per cent of the material. Where iron oxide or clay does not occur with the gravel, and where limestone pebbles are also lacking, the most commonly added binding material is clay. Clay for such use should possess the same characteristics as the clay similarly used in sand-clay roads. (See page 81).

As is the case with sand-clay roads, gravel roads too often prove defective because of too much binder rather than too little. It is generally believed the best results can be obtained from a gravel having from 8 to 15 per cent clay. Heavy auto traffic is particularly hard on gravel roads containing an excess of clay, hence in some localities less than the required amount of clay is used and the attrition of the pebbles by traffic is depended upon to supply the additional fine material or binder. (See pages 33-34.)

J. R. Gregory[1] recommends the use of washed gravel screened to pass a 2-inch ring, the pebbles larger than 2 inches to be crushed and returned with the dust to the main body of gravel. Sand, if needed, should be added so that it makes up at least 35 per cent of the total volume, but not more than 40 per cent.

The relative proportions of pebbles and clay can be easily determined by shaking a known volume or weight of the gravel in a glass jar and allowing it to settle. The clay and finer materials will form a layer above the pebbles, which can be measured and its percentage of the whole readily determined.

Strength of the pebbles.—Since a road gravel should be largely composed of pebbles with a minimum amount of binder, it is essential that these pebbles be sufficiently durable to resist the wear of traffic. The pebbles composing Georgia gravels are mostly of vein quartz and, in a few instances, fragments of tough crystalline rock, and consequently capable of great wear. In some places, pebbles that have been exposed to weathering or erosive influences for long periods, become decayed and show a tendency to easily break up into smaller fragments and even into dust. Such a constituted gravel would of course be of little value in road building, since an excessive amount of binding material would soon be produced by the attrition of the pebbles under ordinary traffic, causing the road to become muddy and "rutty" after rains and dusty in dry weather

Where a choice of gravel exists, a casual inspection of the pebbles will often aid in selecting the most durable material. By breaking the pebbles with a hammer, an approximate idea of their toughness may be had. The relative proportion of durable and decayed pebbles can then be found by a simple measuring or weighing device. In examining two gravels, pebbles of the same size from each gravel should be compared, since the larger pebbles sometimes differ radically in composition from the smaller ones.

In the counties of the Georgia Paleozoic area, (northwest Georgia), limestone, chert, and shale frequently make up a large percentage of the stream gravels. Although limestone pebbles are less resistant than quartz, they possess a high cementing value since the limestone dust worn from them is an effective binder. Shale and sandstone pebbles, on the other hand, readily break up into clay and sand respectively, and a preponderance of either will soon cause a

1 Excerpt supplied by Am. Assoc. of Sand & Gravel Producers, Chicago, Ill.

road to go to pieces. Chert is a brittle material, and its dust makes a fair binder. Small quantities of decayed chert are not generally harmful.

The *shape* of the constituent pebbles has a less important bearing on the value of a gravel. Sharp, angular, fragments bind much more readily than rounded pebbles and form a less mobile gravel. The movements of angular pebbles in the road bed are restricted due to their more frequent contact with each other and the stability of the road under pressure is greatly increased. Chemical reactions between the pebbles are facilitated when the number of points of contact and the pressure are increased. It is well known that solution is produced when moist particles are in contact under pressure. The dissolved material is later deposited where less pressure exists. Stream gravels usually contain rounded pebbles and bank gravels contain a larger percentage of angular, or sub-angular, fragments.

Grading of the pebbles.—For the same reason that the sand to be used in sand-clay roads should be well-graded, the pebbles making up a road gravel should contain as nearly as possible equivalent amounts of pebbles of each size. The spaces in such a gravel will be filled by smaller pebbles, and all the pebbles will be in contact at the maximum number of points, and a minimum of the less resistant binder will be required. But grading is not essential in road gravel, since the constant attrition of traffic will usually make up for the voids deficiency in a short time. In general, the pebbles of a gravel are naturally well-graded. Almost universally, however, pebbles of too large a size occur, and these must be screened out. Such pebbles tend to work to the surface causing rough places, or become loosened, and cause holes around which the road surface may break up.

In the field a ready determination of the ratio of pebbles to finer material may be made by passing a sample of the gravel through a ¼-inch screen and then finding the proportions of clay to the entire sample and to the fine material by washing out the clay (see page 9 for field test for clay percentage). Such an analysis will show what proportions of coarse or fine material must be added or removed in order that the grading will conform to the limits most desirable for road gravels. Where the traffic is not exceptionally heavy a large amount of sand in the gravel is not especially harmful provided there is sufficient binder present. Such gravels will produce a road tending to resemble the sand-clay type.

Baker[1] made a mechanical analysis of 12 good road-making gravels from various parts of theUnited States, and found that the sand (unsuspended material under ¼ inch) ranged from 23 to 73 per cent of the total, and that in 9 of the 12 gravels the sand exceeded 57 per cent. Moorefield[2] gives the following limits of fine and coarse material inla road gravel:

"1. Material retained on a ¼-inch sieve, 55 to 75 per cent.
2. Material retained on a ¾-inch sieve, not less than 15 per cent.
3. Material (clay) passing a 200-mesh sieve for the surface course, 8 to 15 per cent.
4. Material (clay) passing a 200-mesh sieve for the foundation course, 10 to 15 per cent.

The sand content should be at least twice as great as the clay content, and the sand and clay, when thoroughly mixed, should be sufficient to fill the voids between the larger gravel particles. The percentages given above usually will conform to this requirement. The maximum limiting size for the pebbles ordinarily should be from 2½ to 3 inches, because where larger pebbles are permitted in the surface the rate of wear is made unequal, and it is more difficult to maintain a satisfactory bond between the different particles."

The following limits are recommended by the United States Office of Public Roads for gravel to be used in the construction of gravel roads:

BASE COURSE

"All to pass a 2½-inch screen and to have at least 55 and not more than 75 per cent retained on a ¼ inch screen.

"At least 25 and not more than 75 per cent of the total coarse aggregate (material over ¼ inch in size) to be retained on a 1 inch screen.

"At least 65 and not more than 85 per cent of the total fine aggregate (material under ¼ inch in size) to be retained on a 200 mesh sieve."

The cementing value of the material under ¼ inch to be at least 50.

TOP COURSE

"All to pass a 1½ inch screen and to have at least 55 and not more than 75 per cent retained on a ¼ inch screen.

"At least 25 and not more than 75 per cent of the total coarse aggregate to be retained on a ¾ inch screen.

"At least 65 per cent and not more than 85 per cent of the total fine aggregate to be retained on a 200-mesh sieve."

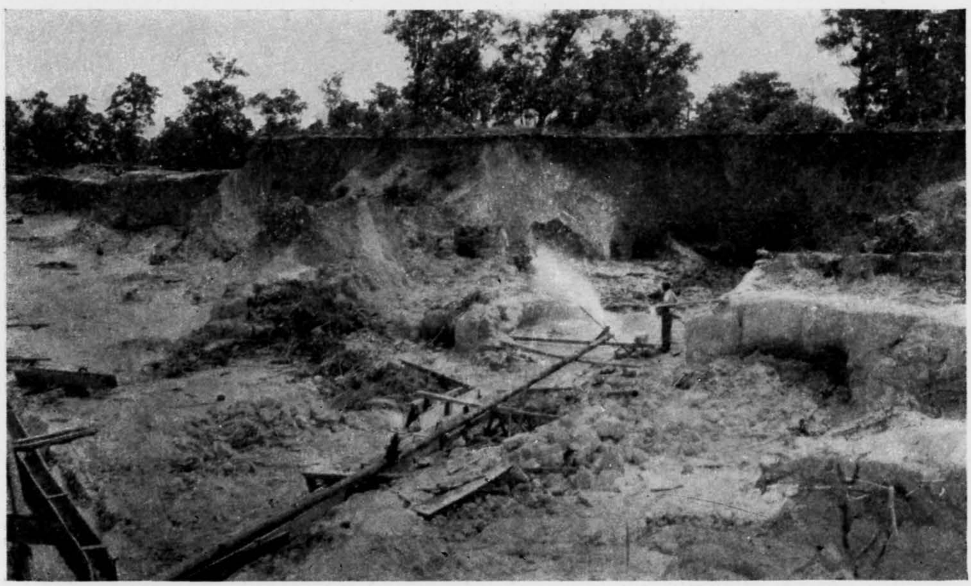
The cementing value of the material under ¼-inch to be at least 50.

In the construction of Michigan state roads at least 60 per cent of the pebbles must be larger than ⅛ inch, while the largest pebbles must pass a 2½-inch ring. Such pebbles can be used only in the bottom course. Clay must not exceed 10 per cent of the whole. In New Jersey, gravel with over 5 per cent retained on a 1½-inch ring and over 35 per cent retained on a ½-inch ring is rejected.

---

1 Baker, I. O., Roads and pavements, p. 156-157.
2 Moorefield, C. H., Earth, sand-clay, and gravel roads: U. S. Dept. Agr., Bull. 463, p. 52, 1917.

A. INTAKE AND PIPE-LINE, GEORGIA SAND & GRAVEL COMPANY, AUGUSTA, RICHMOND COUNTY



B. MINING SAND HYDRAULICLY, ATLANTA SAND & SUPPLY COMPANY, 1 MILE SOUTH OF GAILLARD, CRAWFORD COUNTY

On the other hand, Illinois permits gravel containing uniformly graded pebbles up to those just passing a 3½-inch ring. Not more than 5 per cent loam should be present but it must contain 15 to 20 per cent clay by dry measure.

In roads made up of one course only the coarser pebbles should be placed at the bottom of the gravel. Even in two-course construction work, unless the bottom course is to exceed four inches it is unwise to use stones larger than 3 inches.

It is thus seen that the range of opinion regarding the best kind of road gravel is wide. The most essential quality of a good gravel is a binder of high cementing value. Clay in a gravel does not indicate that the gravel will make a hard road surface. Even though a gravel should be entirely lacking in clay or fine sand, the dust abraded by traffic from certain types of component pebbles, particularly limestone, will soon render the gravel surface hard and durable.

SAND-CLAY ROADS

Perhaps the most common use of sand throughout the Georgia Coastal Plain is in the construction of sand-clay roads. The stability and life of such roads depend largely on the character and proportion of the sand used in the sand-clay mixture. In some counties these roads are hard and durable in all kinds of weather, comparing favorably with gravel roads, but elsewhere the so-called sand-clay roads are little better than dirt or clay roads.

Since the materials for the construction of excellent, durable, sand-clay roads are almost universally found in the southern and eastern parts of the state at least, there appears to be little excuse for poor roads in this section. In the Piedmont portion, careful examination on hill slopes will generally reveal sand clay mixtures which can be made into excellent roads, if from 10 to 40 per cent of stream sand is added.

The construction materials generally occur in three conditions: (1) A natural mixture of sand and clay, often suitable without alteration for use on roads, or less easily rendered so by the addition of small amounts of clay or sand, (2) A naturally sandy soil with clay deposits beneath or in certain parts of the region, (3) A natural clayey soil with sand deposits composing the smaller proportion of the materials.

THE SAND AND THE CLAY

Sand comprises from 70 to 90 per cent of the mixture. Normally there should be just enough clay to fill the voids between the sand when the grains are all in contact. If there is an excess of clay, then the sand grains are free to move about in the mass and no grain is able to resist pressure more than what might be expected from a mass composed entirely of clay. With too little clay, on the other hand, the mixture, lacking binding power, will quickly disintegrate.

The proportion between the sand and clay is also affected by the fineness of the sand, since fine sand usually contains more voids, and hence requires more clay to fill them. The most desirable sand, then, should be coarse-grained, and the grains should be angular. A plastic or "sticky" clay will require more sand than one not so plastic. Clay may be tested[1] by wetting the thumb and placing it against the clay. If it sticks to the thumb, then the clay is good for sand-clay roads. A plastic clay is usually much more desirable than a porous clay. However, some clays have a high shrinkage, so that when they dry out they contract. When water is added the clay expands, if clay of this type is used in a sand-clay road, the grains of sand are forced apart and the surface of the road weakened. In a dry climate the proportion of clay should be larger than in wet climates.

The best way to determine the value of a mixture, either natural or artificially blended, is to make a short strip of test road and watch the effect of weather and traffic upon it. Since local conditions may require a proportioning peculiar to a particular region, an examination of the material composing a road which is giving staisfaction in a locality will be valuable as a standard with which to compare available sand-clay mixtures in that locality. Material so taken from the wearing surface of the road should be tested for the proportion of sand and clay after the manner described on page 9. The grading of the sand should also be determined by screens.

A simple field test of the available materials may be made as follows:[2]

"Take samples of each of the available sands and clays and make a set of small uniform-sized spheres. Use varying proportions of the sands and clays and take care that the material for each sphere is well worked. Place these spheres in the sun and let them bake hard. Note which ones show the most and largest cracks. These represent the mixes which would probably go to pieces in dry weather. Now place the spheres in a shallow pan of water; note which ones disintegrate first. These represent

1 Pratt, J. H., Good Roads Inst., North Carolina Geol. and Econ. Survey, p. 27, 1917.
2 Coghlan, B. K., Sand-clay roads: Texas Eng. Exper. Sta., Bull. 19, p. 8.

the mixes which would not stand up under traffic during wet weather. Some samples will usually be found which neither check badly in drying nor disintegrate quickly when wet. These should be used as a guide for the mixing of the material in the construction of the road.

Since the amount of clay required to mix with the sand depends on the voids percentage of the sand a determination of this will show the approximate amount needed. The voids percentages have been found for many Georgia sands and these are listed herein. A simple method of finding the amount of clay needed to fill the voids in a unit quantity of a given sand is described by W. L. Spoon:[1]

"Two ordinary glass tumblers of the same size are filled to the brim, one with the dry sand, to be tested, and the other with water. The water is then poured carefully from one glass into the sand in the other until it reaches the point of overflowing. The volume of the water taken from the glass which was originally full of water can be taken as an approximate measure of the voids in the unit volume of sand contained in the tumbler. A simple calculation will reduce this to percentage volume."

The U. S. Bureau of Public Roads recommends the following specifications for a natural top-soil or sand-clay mixture:

"To have not more than 10 per cent retained on a ¼-inch screen, at least 10 and not more than 50 per cent on a 20-mesh sieve, at least 30 and not more than 80 per cent on a 50-mesh sieve, at least 45 and not more than 85 per cent on a 80-mesh sieve, and at least 60 and not more than 90 per cent on a 200-mesh sieve.

"To have a cementing value of at least 35."

In localities where a natural sand-clay mixture occurs, which more or less closely approaches the ideal composition for sand-clay roads, a simple treatment[2] may be used to determine it qualities Take a known amount, about two pounds, of the natural soil, and after grinding up the coarse particles in a mortar, place it in a shallow pan and thoroughly wash out all of the clay. Then dry and weigh the sand remaining and compute the amount of clay contained in the natural sample. The next step is to determine the percentage of voids in the washed sand by the method described on page 83. From the percentage of voids we can easily find the amount of clay actually needed to fill the voids in the sand. This amount is then subtracted from the total amount of clay in the sample leaving usually an excess of clay. The amount of sand needed to utilize the excess clay can easily be determined, since the ideal proportion of sand to clay has already been found. From this we can easily find the percentage of sand to be added to the natural sand-clay mixture to obtain one of ideal proportions.

1 Sand-clay and burnt-clay roads: U. S. Dept. Agr., Farmer's Bull. 311, p. 10.
2 Smith J. E., Economic paper No. 39, North Carolina Geol. and Econ. Survey, p. 43, 1914.

Such tests are by no means to be ever considered final, but should serve as a basis upon which to apportion mixtures at first; later observations on the road as its construction proceeds will indicate what mixtures are best.

Mechanical analysis.—Coarse sand is generally considered most desirable for sand-clay roads, since it packs when wet. With fine sands there is little packing, the material assuming the nature of a quicksand.[1] A sand containing uniform amounts of each sized grain is best, since it insures the complete filling of the spaces between the coarser grains by grains of smaller size and guarantees the maximum stability of the mixture. Such grading requires the least clay or binder, which is desirable, since the clay is least able to resist wear. Small pebbles in the sand are also desirable provided there is regular grading of the fine material.

The U. S. Bureau of Public Roads suggests the following specifications of sand for use in sand-clay roads:

"All to pass a ¼-inch sieve, to have at least 5 and not more than 50 per cent retained on a 20-mesh sieve, and at least 50 per cent retained on a 50-mesh sieve."

Moorefield[2] recommends the following simple test of the grading of a sand for sand-clay roads:

"Place a sample of the sand in a vessel containing water and agitate the water until the sand is thoroughly in suspension. Then after the sand has been allowed a few moments to settle, pour off the water slowly. If of good quality the sand will not be carried out with the water, but will remain in the vessel until practically all the water has been drained off. Sand containing a large percentage of mica or other light mineral matter will not meet this test and is not generally suitable for use."

Medium- to coarse-grained, angular sand, then, should constitute the great bulk of the material used in building sand-clay roads. The amount of clay to be added depends on the percentage of voids in the sand and on the plasticity of the clay. The best way to determine the mixture suitable for any locality is to actually test it out in a road, after first making a few preliminary tests.

ASPHALT PAVEMENTS

Sand makes up from 70 to 80 per cent of the wearing surface of asphalt pavements. It is mixed with pulverized limestone and heated, and then thoroughly mixed with asphaltic cement which has been separately heated. This mixture is spread upon the binder course which in turn lies upon a concrete foundation.

---

1 Cogh'an, B. K., Sand-clay roads: Texas Eng. Exper. Sta., Bull. 19, 0. 6,1917.
2 Moorefield, C. H., Earth, sand-clay and gravel roads: U. S. Dept. Agr., Bull. 463, p. 40, 1917

Baker[1] sums up the requirements of a good asphalt paving sand as follows:

"The sand should be clean, sharp, and composed of grains not easily crushed, and have as small a proportion of voids as possible."

If the sand grains are coated with clay or other material, the asphalt can not properly adhere, although clay in separate particles is not particularly harmful. Sharp grains probably allow a better adhesion of the asphalt and prevent less rolling of the pavement under traffic.

The U. S. Bureau of Public Roads reccomends sand of the following specifications for use in sheet asphalt:

"All to pass a 10-mesh sieve, to have at least 20 and not more than 30 per cent retained on a 40-mesh sieve, at least 40 and not more than 50 per cent passing the 40 and retained on the 80-mesh sieve, and to have at least 25 and not more than 35 per cent passing the 80 and retained on the 200-mesh sieve."

Uniformily graded sands since they usually possess fewer voids are desirable. As the asphaltic cement is something of a liquid with capillary action between the sand grains, the smaller the individual pore space the stronger the attraction between the asphalt and the sand.[2] This implies the use of a fine sand. Baker,[3] in speaking of the sand for asphalt paving, says:

" . . . . Fine sand is usually less sharp than coarse and the finer the sand the greater the surface to be coated and hence the greater the amount of asphalt required. The asphalt is not only more expensive than the sand, but it is less able to resist displacement by pressure; and consequently the greater the amount of asphalt present, the more expensive the pavement and the more liable it is to flow under traffic. On the other hand, the smaller the voids, the greater the binding action of the cement; and also the finer the sand, the smaller the voids (interstices), although the per cent of voids may be greater than with sand having grains of graded sizes."

As pulverized limestone is added to fill the voids between the coarse and fine sand grains and to make the individual interstices smaller, so that the capillary action may be increased, it would seem that a large amount of fines in sand for asphalt paving would, therefore, be a very desirable feature. Sand with a large voids percentage allows the asphalt to work down through it in hot weather, and the surface of the pavement is then likely to crack in cold weather.[4]

---

1 Baker, I. O., Roads and pavements, p. 410, 1913.
2 Op. Cit., p. 411.
3 Op. Cit., p. 411.
4 Op. cit., p. 414.

Of two sands used in paving Washington streets, that containing 42 per cent of its weight under 60 mesh proved more satisfactory than another containing only 22 per cent passing 60 mesh.[1]

Richardson in speaking of the requirements of asphalt paving sand says, in part:[2]

"A clean sand is in any case probably more desirable, although satisfactory results have been obtained with many loamy ones . . . . . Organic matter in the shape of vegetable debris is sometimes found in sand. It is usually removed in screening. . . . . . If this is not possible and the amount remaining is excessive the sand should be rejected.

"*The shape of the grains*[3] of a sand has a marked influence, when combined with their size and grading, upon the character of the asphalt surface mixture made with them. . . . . Mixtures made with round-grained sands are of course less stable than those made with sharp sand, since round particles move much more readily over one another than sharp ones; but, on the other hand, with plenty of filler this tendency can be neutralized, while the round-grained sands can be packed much more readily and closely and with smaller voids and the resulting surface can, in this way, be made denser.

"*Surface of Sand*[4]—The different kinds of surfaces behave quite differently toward asphalt cement. The porous limestone surfaces absorb it, and it, of course, adhere very firmly. To the quartz surfaces the bitumen adheres, in most cases, well.

"*The size of sand grains*[5] in an asphalt pavement, that is to say, their average diameter, is of the greatest importance. . . . In a standard sheet asphalt surface it has been found generally preferable to have no sand grains larger than 2 millimeters in diameter, passing a 10-mesh sieve made of wire 0.027 inches in diameter, or smaller than 0.17 millimeter, which pass a sieve of 100 meshes to the inch, made of wire 0.0043 inches in diameter."

Richardson probably believes fine sands are much more desirable since he says[6] in speaking of a Kentucky asphalt sand:

"The sand grains are extremely coarse, the majority of them being of 40 and 50 mesh in size in one instance, and larger than 30 mesh in another. Such a sand grading alone would make this material unsuitable for use in an asphalt surface."

Mr. H. L. Collier,[7] chief of the Construction Department of the city of Atlanta, favors a fine-grained, dustless sand for use in asphalt paving, most of which will pass a 50-mesh sieve and be retained on an 100-mesh sieve.

Just as coarseness of grain is the most important characteristic of concrete sands, it would seem that fineness of grain is the most important characteristic of asphalt paving sands. Sands containing from 50 to 70 per cent of their weight between 48 and 100 mesh are probably most desirable in the long run, for asphalt pavements.

---

1 Op. cit., p. 413.
2 Richardson, Clifford, The modern asphalt pavement, pp. 53-56.
3 Op. cit., p. 57.
4 Op. cit., pp. 57-59.
5 Op. cit., pp. 57-59.
6 Op. cit., p. 224.
7 Oral communication.

SAND-OIL ROADS

In parts of Florida and Massachusetts[1] hot asphaltic oil has been added to sand to make roads. In Massachusetts 1½ gallons of the oil were used to each square yard of road, and the resulting surface was excellent for light teams and automobiles. The sand should be sharp, hard, and well-graded rather than uniform or fine-grained.

PAVING SAND

Sand and gravel are widely used as foundation or cushion layers where the streets are constructed of brick, wood, and stone blocks, or asphalt, and also as a filler between the blocks. In 1919 Georgia produced 21,284 tons of paving sand valued at $12,320.

PAVEMENT FOUNDATIONS[2]

Usually sand and gravel are the cheapest forms of foundation for brick, wood, or stone-block pavements, and in many cases, where the traffic is comparatively light, are the most desirable, since they permit of excellent drainage. For ordinary subsoil, 5 inches of gravel, overlain by 3 inches of clean sand, makes an excellent foundation. Where the sub-grade is clay or muck, 10 or 12 inches of sand is required. Sand foundations should always be rolled. Sand and gravel used as a foundation should not contain more than 15 to 20 per cent of clay.

CUSHION SAND

In the construction of brick or wood- and stone-block roads, streets or pavements, the sand support, or cushion, upon which the bricks and blocks are laid, is a very important feature. Such a cushion is primarily intended to smooth out the irregularities existing in the top of the base and give elasticity to the pavement. The sand must be free from pebbles, clay, loam, and other materials likely to become sticky or greasy when wet.

Tebbs[3] says that in Pennsylvania 15 per cent loam is permitted in the sand, which prevents the shifting about, characteristic of a clean, dry sand. Larger amounts will cause settling of the bricks when the loam is washed to the bottom. A reasonably dry sand should be used thus preventing the settling consequent to the drying of the sand and its resultant shrinkage in volume. Since the function of

---

1 Good Roads Year Book, pp. 402-403, 1917.
2 Buckley, E. R., Public roads: Missouri Bur. Geology and Mines, p. 42, 1907.
3 Good Roads Year Book, Brick roads, p. 421, 1917.

the sand cushion is largely to smooth out the inequalities in the base, the thinner it is the better, thus avoiding shrinkage. A cushion from 1 to 1½ inches thick is usually quite satisfactory.

At the present time in brick road paving the sand-cement mortar cushion having a ratio of 1 to 3 or 1 to 4 is replacing the sand cushion, since the latter has not given satisfaction when the road is subjected to heavy jars. In the case of asphalt pavements, the binder course, composed of bituminous concrete, has taken the place of the cushion sand.

FILLER SAND

Sand (now usually replaced by cement grout or tar) forms a cheap filler without damaging the brick when the pavement is taken up. It is easily washed or swept out, however, and does not prevent the edges of the brick from chipping. It has proved very satisfactory in wood-block pavements.[1]

RAILROAD BALLAST

Most of the gravel now used for railroad ballast in Georgia has been brought in from Alabama, although a number of years ago gravel was extensively used from a pit on the Central of Georgia Railway near Georgetown.

Chert gravel has been used in northwest Georgia, and large quantities were formerly quarried near Summerville. The Southern Railway at present is using a partially disintegrated quartzite schist from extensive pits near Alto. Cinders, crushed rock, and sand are also generally used throughout the state; and elsewhere, clay, burnt clay or burnt gumbo, and chert are extensively used.

The function of ballast is to make a stable, resilient road bed, which will quickly drain off water preventing the decay of ties. There is considerable diversity of opinion as to the relative merits of gravel and crushed stone for railway ballast. Gravel is usually cheaper and permits greater ease in tie renewals, but has the disadvantage of dust, inability to hold the surface under extremely heavy loads, and permits the growth of weeds. Many believe gravel makes an easier riding road-bed. If the gravel is well-graded, a more solid foundation of much higher binding power is secured. A ballast gravel should contain sand to fill up the voids between the pebbles. Clay hinders the drainage, makes a dusty road-bed in dry weather, and encourages the growth of weeds.

1 Tillsen ,G. W. Am. Soc. Civil Eng. Trans. Vol. 75 ,pp. 530-532.

The Committee on Ballasting of the American Railway Engineering and Maintenance of Way Association has made the following statements and recommendations[1] regarding the use of gravel for railroad ballast:

"1. Gravel with much over 3 per cent of dust does not drain freely; with less than that amount drainage is good.

2. Gravel with less than 2 per cent dust makes a fairly dustless road-bed.

3. Pebbles should not exceed 2 inches in size. Larger pebbles should be crushed and returned to the ballast.

4. Less than 20 per cent sand permits pebbles to shift, under load, and over 50 per cent prevents ballast from becoming firm.

5. The Committee recommends for

Class 'A' roads, 10 parts gravel and 3 parts sand. Bank gravel with over 2 per cent dust or 40 per cent sand should be washed and screened.

Class 'B' roads, 10 parts of gravel and 6 parts sand. Bank gravel with over 3 per cent dust or 60 per cent sand should be screened or washed.

Class 'C' roads, 10 parts gravel and 10 parts sand. Any gravel not over 6 per cent dust may be used."

Classes A, B, C, refer to the amount of traffic handled and are described in the manual of the American Railway Engineers' Association.

The following test[2] made on pit gravel used for ballasting show the effect of sand and clay (dust).

Characteristics of ballast gravels

Gravel, Per cent	Sand, Per cent	Dust, Per cent	Remarks
81.6	27.0	1.3	Very good.
61.3	50.9	2.8	Fair.
86.0	12.5	6.5	Poor cementing nature.
59.6	55.4	3.6	Good but dusty—sand excess increases labor.
58.7	49.1	12.9	Very poor.

Gravel near Omaha and Columbus and also near Warrenton was formerly used for ballast, but owing partly to exhaustion of the more accessible material and partly to opening of larger and more cheaply worked deposits in Alabama, its use has been discontinued. Large

1 Engineering News, Vol. 61, pp. 404-405, April 15, 1909.
2 Op. cit.

deposits, however, await development within a mile or two of railroads, particularly along the Fall Line and along Chattahoochee River. Most of this material is better suited for road purposes than for ballast because of comparatively large amounts of clay.

FILTER SAND AND GRAVEL

In a way, sand is the most important part of a water filtration plant. Specifications for filter sand and gravel have been investigated in considerable detail, particularly by Hazen.[1]

Filter sands, contrary to the requirements for concrete sands, should be as uniform in grain size as possible. Freedom from clay and organic matter is of course essential. The terms "uniformity coefficient" and "effective size" (see pp. 27-28) have been introduced largely for the purpose of describing filter sands.

The specifications for the filtration plant at Washington, D. C., for which over 180,000 cubic yards of sand and gravel were required, were as follows:[2]

"*Filter gravel.*—On the floor of the filters and surrounding the underdrains shall be placed gravel or broken stone having a maximum depth of 1 foot. Instructions will be given by the Engineer officer in charge as to the exact arrangement and positions of the various layers when the stone commences to be received upon the ground, but the arrangement will be approximately as follows: The lower 7 inches shall consist of broken stone or gravel which will remain upon a screen with a mesh of 1 inch, and which has but very few stones over 2 inches in diameter. Above this shall be placed 2½ inches of broken stone or gravel which has passed a screen with a mesh of 1 inch, and which remains upon a screen with a clear mesh of ⅜ inches. Above this shall be placed 2½ inches of broken stone or gravel, which has passed a screen with a mesh of ⅜ inch, and which is coarser than the ordinary sand, and entirely free from fine material.

"The material for all of the layers may be broken trap rock or granite screened to the proper sizes, or gravel screened from sand and gravel banks of a sandy nature. Gravel screened from hardpan or clayey material can not be sufficiently cleaned. The gravel shall not contain more than a very small amount of shale or limestone. The gravel shall be washed entirely free from fine material, so that water passing through it or agitated in contact with it will remain substantially clean.

"*Filter sand.*—The filter sand shall be clean river, beach or bank sand, with either sharp or rounded grains. It shall be entirely free from clay, dust, or organic impurities and shall, if necessary, be washed to remove such materials from it. The grains shall, all of them, be of hard material which will not disintegrate and shall be of the following diameters: Not more than one-half of 1 per cent by weight shall be less than 0.13 millimeter; not more than 8 per cent less than 0.26 millimeter. At least 7 per cent by weight shall be less than 0.34 millimeter, at least 70 per cent less than 0.83 and at least 90 per cent less than 2.1 millimeters. No particle shall be more than 5 millimeters in

1 Hazen, Allen, Some physical properties of sands and gravels: Massachusetts State Board of Health Rept., p. 541, 1892.
2 Stone, R. W., Mineral resources of the United States for 1913, pt. 2, pp. 336-337, 1914.

diameter, and the sand shall be passed through screens or sieves of such mesh as to stop all such particles, and no screen or sieve shall be used containing at any point holes or passages allowing grains larger than the above to pass. The diameters of the sand grains will be computed as the diameters of spheres of equal volume. The sand shall not contain more than 2 per cent by weight of lime and magnesia taken together and calculated as carbonates. In all other respects the sand shall be of a quality satisfactory to the Engineer officer in charge.

"The filter sand shall be placed in the filters in three layers, each layer to be about 1 foot thick, and the sand shall not be dropped from a height into final position or otherwise unduly compacted. The first two layers may be filled in to only approximate depths and the surfaces need not be smoothed. The final layer shall be brought to a true and even grade, and the surface left smooth and uniform."

The sand and gravel specifications at the Queen Lane filters, in Philadelphia, contained the following requirements:

Least effective size of sand	0.30
Greatest " " " "	0.38
Least uniformity coefficient	1.70
Greatest " "	2.70

The sand and gravel sizes were placed in the following order in the filter beds of the Queen Lane plant:

1.	3- to 2- inch gravel	6 inches
2.	1½ " ⅝ " "	4 "
3.	½ " ¼ " "	3 "
4.	¼ " ⅛ " "	2 "
5.	Through 8 mesh with less than 0.5 per cent passing 20 mesh	1 "
6.	Sand	26 "

The sand used in the filters at the waterworks supplying Atlanta, Ga., must pass a 20-mesh screen and be retained on the 40-mesh. It must be clean, sharp, and free from clay and dirt. The sand in filters must be washed every year or so to free it of the accumulated sediment collected from the water. A certain proportion of the original sand, from 10 to 20 per cent, must be replaced each year, due to the wearing out or breaking up of some of the grains. In the case of the Atlanta filtration plant from 2 to 3 carloads yearly must be supplied.

Filter sand produced at Crystal City, Missouri,[1] conformed to the following specifications:

"The sand shall be composed of hard and durable grains, either sharp or rounded, substantially free from clay, loam, dust, or organic matter and flat particles.

"When the sand, crushed and powdered, is digested for twenty-four hours in strong, warm hydrochloric acid, without stirring, at least 95 per cent shall remain insoluble. The sand shall not contain more than two per cent of calcium and magnesium, taken together, and calculated as calcium carbonate ($CaCO_3$).

---

1 Dake, C. L., Sand and gravel resources of Missouri, Missouri Bur. Geology and Mines, Vol. XV, 2d ser., p. 80, 1918.

"The sand shall have an effective size of not less than 0.40 nor more than 0.50 of a millimeter and a uniformity coefficient not greater than 1.65. Not more than one-fourth of one per cent shall be finer than 1.2 millimeters. The diameters of sand grains shall be computed as the diameters of spheres of equal volumes, and all percentages shall be calculated by weight."

Some of the washed grades from the Taylor and Crawford counties pits have been used throughout the state in filters and compare very favorably with sands brought from a distance.

ENGINE AND TROLLEY SAND

A large amount of the sand produced in South Georgia from the fluvial sand hills is used by the railroads to sand rails to facilitate the action of the driving wheels of the locomotives. In the southern states, with the heavy rainfall and persistence of vegetation along the track throughout the year, the demand is probably uniform in all seasons. In northern states, however, spring and summer produce the greatest demand. In 1919 Georgia produced 9,091 tons of engine sand valued at $4,988.

Condra[1] says such sand should be hard, sharp, clean, and of a medium degree of fineness. It should be sufficiently coarse to remain on the rails in a moderately strong wind, and free from clay, twigs, and pebbles, which will clog the feeding pipes, or prevent the free running of the sand in these pipes. For the same reason the sand must be quite dry. Most locomotive and trolley sands are artificially dried. As high a quartz content as possible is desirable to insure the grains from being crushed to an impalpable powder.

Practically all of the South Georgia sand conforms to these specifications for engine sand.

The Georgia Railway and Power Company, operating the street cars in Atlanta, obtains its sand from Terrill and Proctor creeks, near Atlanta, and from the west bank of Chattahoochee River, near Bolton.

ROOFING GRAVEL

Roofing gravel is used extensively in buildings having practically flat roofs. It is usually a screened product retained on a ¼-inch screen and passing a ¾-inch screen.[2] The pebbles should preferably

1 Conda, G. E., Sand and gravel resources and industries of Nebraska: Nebraska Geol. Survey, Vol. 3, pt. 1, pp. 186-190, 1908.
2 Dake, C. L., Sand and gravel resources of Missouri: Missouri Bur. Geology and Mines, Vol. XV, 2d ser., p. 63, 1918.

be rounded to prevent cutting of the tar-paper base, and sufficiently coarse to prevent removal from the roof when the tar is melted by the sun. Sometimes stone crushed to small sizes is used for roofing purposes.

So far as the writer could learn, no roofing gravel is now being produced in Georgia, although about 1900 some was shipped from the vicinity of Kingston, in Bartow County

ABRASIVE USES

SAND-BLAST

Considerable sand is used in sand-blasts for cleaning and smoothing casting faces, for removing paint from steel structures preparatory to re-painting, and for cleaning stone surfaces of large buildings. Sand for this work should be hard, containing as much quartz as possible, sharp, moderately coarse, new, and free from clay. It should preferably be uniform in size and should pass an 8-mesh screen. Much of the Taylor and Crawford County sand of Georgia is suitable for such work.

Cape May grit, from the southern coast of New Jersey, composed of rounded ovoids and containing over 98 per cent silica, has proved an excellent sand.[1]

The granulometric analysis of this material is as follows:

Mechanical analysis of Cape May grit

Passing			
8 mesh	10 mesh	20 mesh	30 mesh
20%	70%	3%	trace

STONE SAWYER'S SAND

In the marble district of Georgia considerable sand is used with the steel saws cutting the large blocks of marble as they come from the quarries. Similar sand, free from coarse grains or pebbles, is used in the rubbing beds to give the initial smooth surface to the marble.

Sand for this work should be usually hard and sharp, with as large

1 Sand blast machine, Am. Soc. Mech. Eng. Trans., Vol. 33, pp. 835-840.

a quartz content as possible, uniform in grain size and free from clay.

The Taylor and Crawford counties sand proves very satisfactory in the Georgia marble finishing works, although some fine-grained sand from local stream bars is used. Sometimes a layer of very angular sand occurs in the sand pits and care in the selection of this bed in filling orders from the marble works would be desirable.

GRINDING AND POLISHING

Some sand is used to polish wood, stone, glass, and similar surfaces. Such sand should be hard, preferably all quartz, particularly that for use in glass polishing, sharp, uniform in size, and free from coarse grains likely to scratch the polished surface.

SAND-CEMENT

In large engineering projects in the West, such as the construction of dams, aqueducts, and reservoirs, ground sand or siliceous rock has been blended with cement and a product obtained that has apparently given satisfaction and materially reduced the cement costs.

In the case of the Arrow Rock dam in Idaho,[1] a plant was constructed at a cost of $40,000 for this purpose. To the cement, 40 per cent of ground siliceous rock was added, and a saving of $250,000 was affected.

FIRE-SAND

Fire, or furnace sand, is used with either a lime or fire-clay binder, for lining and patching furnaces, converters, cupalos, and ladles for containing molten metal.[2] This sand should contain as high a silica content as possible, preferably 97 per cent or more, to prevent fusing when in contact with molten metals. Its requirements so far as can be learned, are similar to those of steel molding sand. (See pp. 68-69.)

MINOR USES

In addition to the uses already enumerated, many of less importance may be tabulated. Such uses include sand used for bedding stock cars, which should be free from pebbles and clay, and permit proper drainage.

In California, and in other regions subject to high winds carrying sand, clean, white sand is evenly applied to freshly-painted surfaces,

1 Eng. Record, Vol. 65, p. 320, 1920.
2 Dake, C. L., op. cit., p. 85.

thus preventing abrasion of the wood and adding somewhat to its appearance.

Clean, white sand is used to provide play places for children, and also in certain mechanical toys. Sand is also used on sand-paper, in scouring soaps, and when ground to pass 120 mesh and containing less than one per cent iron, as a constituent of pottery glazes. Sand, free from pebbles and lime, is added to clay to reduce shrinkage. Finely ground silica or "silex", is used in the manufacture of paints for outdoor use, in the manufacture of various chemicals, metal polishes, silicon and its alloys, and in the production of silica apparatus for laboratory uses. Sand used in the manufacture of carborundum must contain over 99 per cent silica and be preferably of even grain. Sand makes up over 50 per cent of the raw material in this product. Round-grained, even-textured sand between 80 and 100 mesh in size is required for hour-glasses.

White, dustless sand, approximately 65 mesh in size, is used by roofing companies to dust the coatings of tar paper to prevent sticking. Sand is also added to sweeping compounds.

Sand, owing to its incoherency, makes an excellent filler for fertilizers, and large quantities are used for this purpose. In engineering work sand has been successfully used in filling mines, particularly the anthracite mines of Pennsylvania. Sand in huge sand-boxes is used to lower bridge spans or other heavy loads supported on the boxes. Crystalline quartz and sand have been used in the manufacture of silicon and its alloys with various metals.

METHODS OF TRANSPORTATION, PRODUCTION, AND PREPARATION

In handling bank sand in most of the sand-producing regions of Georgia, hand labor is still largely employed, although the use of steam shovels, car loaders, and other mechanical contrivances are being slowly extended. Stream sand is produced more frequently on a commercial scale by mechanical means, but at a few places in the state, production is obtained by hand loading. The following description of methods of producing sand has not been drawn entirely from observations in the state, but it is hoped that it may aid in the selection of suitable labor-saving devices where conditions warrant their substitution for less economical hand methods.

TRANSPORTATION

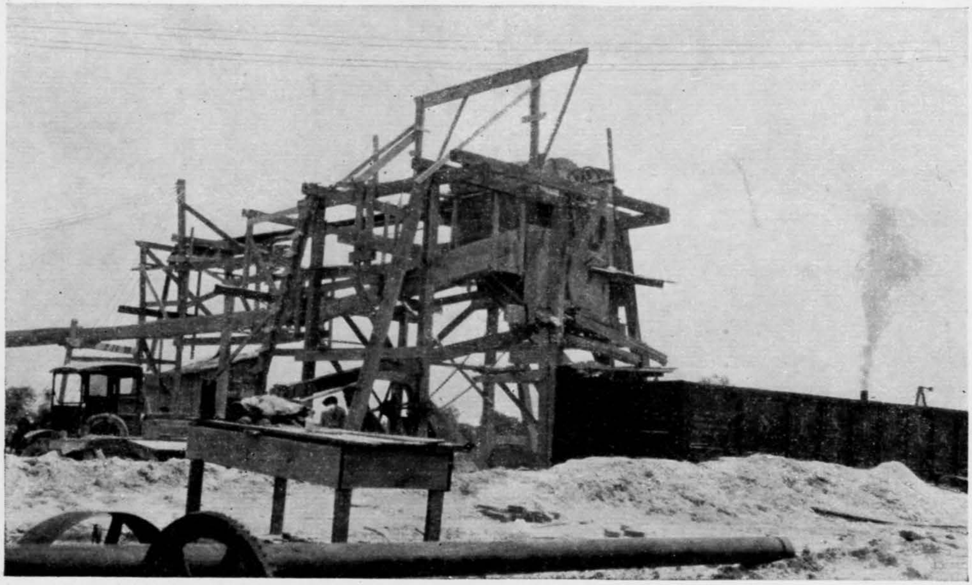
In the case of commodities like sand and gravel, having so little intrinsic value, the item of transportation makes up at least half, and frequently as much as three-quarters of the cost to the consumer. The consumer is therefore interested in reducing the cost of transportation to the lowest figure possible. This may frequently be accomplished by utilizing nearby deposits, provided their quality is sufficiently high, and if modern convenient methods of handling and transportation are used. In some instances heavy transportation charges are assumed in order to get a certain far-famed sand which may be no better and possibly not as good as a local product.

Wagons.—Two-horse wagons are most economical where the requirements are small and the distance from pit to consumer is short. With two-horse wagons more than twice the load can be transported at little more than the expense of one-horse carts. Wagons are more economical than trucks where the haul is only a small fraction of a mile, provided the truck cannot be used continuously. Wagon transportation is usually employed in the smaller towns where the local supply is obtained from a small pit nearby. In some places the pit is common property and anyone can get sand to supply his needs for the expense of hauling; at other places a nominal charge of from 5 to 25 cents a yard is made and the consumer does the hauling, or the owner of the land may agree to keep the deposit free of overburden and even do the hauling, charging from 50 cents to $1.50 a yard for the delivered product.

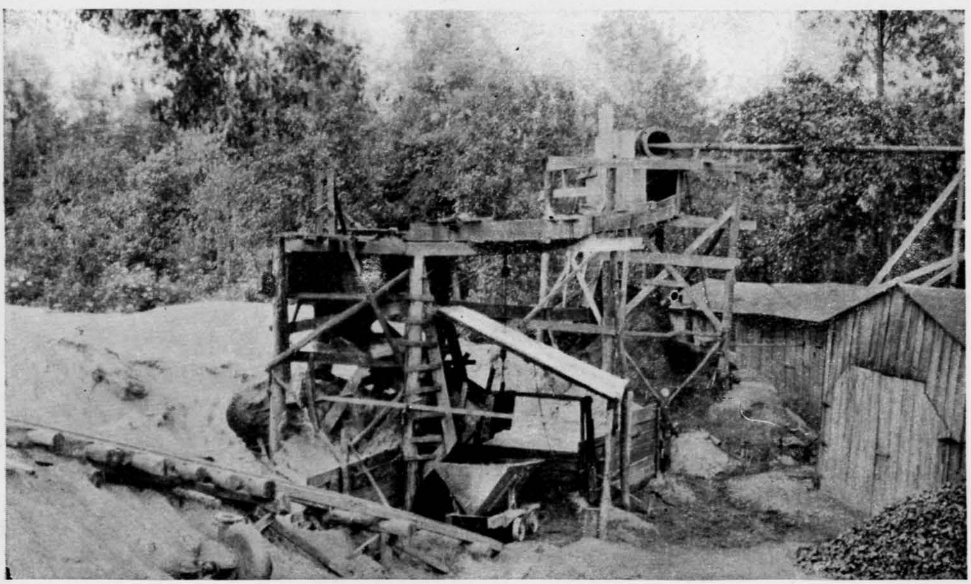
Motor truck.—The advantages of motor haulage of sand and gravel from local pits to the consumer and from railroad cars to the construction job are daily becoming more realized. The length of the haul, of course, depends on the character of the sand and its scarcity. Sand is hauled 2 miles at Fitzgerald, 1½ miles at Quitman, 4 miles at Thomasville, from 1 to 3 miles at Moultrie, and 1 mile at Tifton. In Atlanta, sand from the plant of the Acme Sand Company, on Peachtree Road at Peachtree Creek, is hauled to all parts of the city, the hauls ranging from a fraction of a mile to 5 miles and the price of the sand increasing as the haul increases.

In Youngstown, Ohio,[1] a 5-ton truck with a rear-end dump body,

1 Eng. Record, Vol. 66, p. 473, 1912.



A. WASHING AND SCREENING PLANT, GEORGIA SAND & GRAVEL COMPANY, AUGUSTA, RICHMOND COUNTY



B. WASHING AND SCREENING PLANT, ACME SAND & SUPPLY COMPANY, PEACHTREE CREEK NEAR PEACHTREE ROAD, ATLANTA, FULTON COUNTY and requiring only one minute from the time of arriving at the sand storage bins until it left loaded, regularly made 50 round trips of 1.3 miles each in 10 hours. Two men were required on the truck and it did the work of seven wagons, having the added advantage of being able to operate in all kinds of weather. Assuming the cost of the truck to be $30 a day, then the cost per ton-mile would be 18.5 cents, or less than two-thirds the cost of hauling the sand in wagons. It must be remembered, however, that the value of motor haulage is greatest when it can be employed continuously and where the roads are at least fairly good.

Railroads.—Railroad haul is generally restricted to commercial sand consigned to distant points. In many places the combined expense of railroad freight and drayage from the car to the job at the destination, is more than the expense of hauling sand by wagon or truck directly from a local source to the job.

As the minimum freight rate on sand and gravel differs little on hauls from 10 to 100 miles, the development of nearby deposits is often hampered, since it is more convenient to obtain the sand from established pits. Pits on small railroads, from which sand must be shipped over at least two lines to get to the large markets, can rarely be financially successful, since the sum of two or more short-haul charges will usually equal or exceed the charge for a much larger haul between points on the same railroad.

Although most of the sand and gravel used in Georgia is produced in the state, great quantities are shipped to Atlanta from points in Alabama conveniently situated with respect to through railroads. In this case it is questionable whether much of the Alabama sand is better than, or even as good as, Georgia sand, its use having been largely encouraged by cheaper freight charges.

Short rail hauls of sand and gravel are few in Georgia. Cairo has been obtaining considerable sand from the vicinity of Gradyville, about 3 miles distant by rail, and sand used in Douglas is hauled only 6 miles by rail. In some places advantage is taken of the nominal charge for switching cars from one part of a town to another in transporting sand and gravel.

Boat.—Very little sand is transported by boat in Georgia except where the sand is dredged from the river bed to a scow and then towed to the pier for unloading. This is the case on Savannah River at Savannah and on St. Marys River above St. Marys. At Rome sand is loaded on scows either from islands or along the river banks and then towed to a pier for disposal by land. Practically all of the navigable rivers of Georgia contain inexhaustible supplies of excellent sand. This sand could be loaded on barges or flats and drifted to the nearest railway point.

Most of the smaller scows or barges having capacities of from 10 to 100 cubic yards, are built of wood and of the usual square type, having sides from 12 to 24 inches high. The larger barges, used on Mississippi and Ohio rivers are of either the decked type, used on the Mississippi, and the open-hold type, preferred on the Ohio. The decked barge is best where loading is by centrifugal pump in order to permit the water to drain off. For large production, where unloading is by heavy grab buckets, steel construction is by far the best, since it has three times the life of wood under similar conditions. Large, modern, steel-decked barges now in use on Mississippi River, have capacities of from 300 to 400 yards and are 130 x 30 x 7½ feet. When loaded they draw from 5 to 7 feet of water.

In the Pittsburg district where ladder-elevator dippers are used, open hold barges transport the sand since little water remains in it. Their usual capacity is from 150 to 200 yards and their dimensions about 100 x 24 x 8 feet.

MECHANICAL CONVEYORS

Under mechanical conveyors, belt conveyors and bucket elevators may be considered. Conveyors of this kind are coming into more general use in transporting sand directly from the excavating machine to the screening plant, or in raising it from track hoppers to the top of the plant.

Belt conveyors.—The belt usually has a canvas body with a rubber cover and runs on troughing idlers. Belt conveyors are in use in sand and gravel pits to transport the material from the pit to the washer for distances up to 1,000 feet. It is questionable whether lengths of over a few hundred feet are economical under most conditions. Where the distance from pit to plant exceeds 500 feet it is usually best to deliver the sand in hopper cars.

Table showing capacities and requirements of belt conveyors

Sand and gravel hauled per hour in tons	Distance in feet		Horsepower required	Width of belt in inches
	Horizontal	Vertical		
20	50	10	2	12
40	100	20	3	14
60	150	30	4	16
80	200	40	6	18
100	300	60	8	20
200	400	80	16	26

For elevating sand and gravel, belt conveyors can run at a maximum angle of 20°. The same amount of power will convey on belts five times the distance it will elevate on belts.

Elevators.—Elevators of four types may be used for raising sand and gravel to washing plants. (1) *The continuous bucket elevator,* whose buckets are carried on a chain, requires less space, but is likely to permit of some spillage; (2) The *inclined* or *stone elevator,* which is most generally used, has steel buckets closely spaced on a canvas or rubber belt which operates on a wooden frame. It has a high capacity although running at low speed and is satisfactory, unless the height is too great; (3) The *centrifugal discharge type* discharges the material from the buckets by centrifugal force and is operated at high speed. The cost of this elevator is less than the others, but the upkeep expense is greater, due to its greater speed and consequent wear; (4) The *dredging elevator* obtains its load under water and for this reason is desirable in plants having the sand delivered to a dump or pit by a centrifugal pump. The dredging elevator is inclined farther from the vertical than the other types, thus allowing the empty buckets more slack to aid the digging.

In small sand and gravel plants bucket elevators are said to be more economical than inclined belt conveyors in raising material to the top of the plant. To insure their maximum efficiency, bucket elevators should be installed as nearly vertical as possible.

PRODUCTION METHODS

HAND LABOR

Loading by hand directly into a wagon, railway car, or scow, is common, and in fact usual, throughout Georgia. Colored labor is usually employed for this purpose. The track must be kept close to the working face for the best economy. It is said that one man can load from 10 to 22 yards in a 10-hour day, lifting it from 8 to 10 feet. This method is used entirely where sand is obtained from near-by local pits and hauled to town in wagons and trucks. Although it frequently permits of a better selection of material than is possible with mechanical methods, particularly where the different grades of sand lie in thin beds. In a few cases where the deposit is uniform, and the product does not require preparation before shipment, the use of hand labor may be the cheapest; but installation of mechanical loaders or a small steam shovel would soon pay for itself in decreased costs and increased production in many places. In some of the Crawford County pits several grades of sand occur from 2 to 4 feet in thickness. It would be practically impossible to handle these separately with a steam shovel. This is true of unconsolidated glass sand, where a cover of irregular thickness occurs above the white sand, whose upper surface may also be undulating.

At some places the sand is loaded from the creek bar into wagons, and hauled to railway cars to which it is transferred by hand or by traps (see p. 288). At Mandeville, in Carroll County, sand is loaded into wagons from bars in Bear Creek and hauled to the top of a steep hill, where it is dumped and later loaded into motor trucks for transportation to railroad cars or for local use.

In the spring of 1920 in Georgia the daily wage paid shovelers in sand and gravel pits ranged from $2.50 to $4.00. In a number of places it has been found most desirable to pay a man a certain amount for loading a 30-ton car. This usually insures completion of the work in the least time. The amount paid is usually about $4.00, and many shovelers can load a car and part of another in a day.

Table showing average amount of work and cost of handling sand and gravel[1]

Method	Cu. yards per man per hour	Cost per cu. yard at $0.15 an hour
Sand into cars from high face	1.8	$0.0825
Sand into carts	2.0	0.075
Gravel into wheelbarrows	1.7–2.7	0.07
Gravel into carts	1.0	0.150
Gravel into wagons	1.3	0.113
Average earth	1.75	0.086

Sand from river bars and islands is also loaded on flats directly by hand. The flats are then pushed or towed by a gasolene launch or even poled to a pier, where the sand may be unloaded by hand into wagons or to stock piles. It is said than one man can load 4 to 7 yards in a 10-hour day, the amount depending on the distance the scow must be towed. At Rome, on Etowah River, local dealers load sand into small scows by means of a large dipper attached to the end of a long pole. When the scow is loaded, it is poled to the bank and the sand loaded into wagons.

Wheelbarrows are commonly used in loading cars and flats. Where box cars are used for transporting sand, direct hand loading is impracticable. The wheelbarrows are hand-loaded and then wheeled along planks or rough trestles to the car, generally less than 50 feet away. Wheelbarrows are also used in loading flats and barges in streams.

TRAP LOADING

It may be convenient to construct a bridge over a railroad spur or road with gentle slopes at either side. A hole or trap is cut in the floor of the bridge, and wagons can be driven up the inclines, and their contents dumped directly into waiting railway cars. Drag and wheel scrapers are also used in this manner to load cars, trucks, or

1 Complied from McDaniel, A. B. Excavation machinery, methods, and costs: McGraw Hill Book Co., New York.

wagons. It is usually desirable and economical, in the case of irregular wagon loading, to construct a small bin for storage purposes beneath the trap. By raising a slide a wagon can be filled from the bin at any time. This method is employed at the sand pit on the Fort Benning Reservation near Columbus.

A still better method is to construct a pocket or boot beneath the trap from which the material is carried by some type of conveyor to large bins above. In view of the limited economical haul of the smaller scrapers, it will be necessary to move the platform and trap as the sand is worked out, or else to lengthen the conveyor, so that other traps can be built over it.

Scrapers.—Scrapers are of two main types, horse-drawn and power-operated. Horse scrapers can be used to advantage in pits whose production is not large or those having no rail connections and also in removing the overburden from sand or gravel deposits. There are four types: drag scrapers, two-wheeled scrapers, Fresno scrapers, and four-wheeled scrapers.

Drag scrapers are pulled by one or two horses, have a capacity of from 3 to 6 cubic feet, weigh from 80 to 110 pounds, and cost from $10 to $13 (1920). The cost per cubic yard in average soils for a haul of 50 feet or less is 12 cents. For each additional 50-foot haul the cost increases 3 cents per yard. Such scrapers are most economical up to 100-foot hauls, but for greater distances wheeled scrapers should be used.

Table showing average amount of material handled in 10-hour day by scrapers

Length of haul in feet	Capacity in cubic yards per 10-hour day	
	Drag scraper	Wheeled scraper
25	70	--
50	60	--
100	50	50
150	40	--
200	35	50
300	--	40
400	--	30

Wheeled scrapers are operated by 2, 3, or 4 horses and have capacities of from 7 to 16 cubic feet. Their weight ranges from 400 to 800 pounds, and the cost from $51.00 to $82.50 in 1920. Wheeled scrapers may be economically used up to 400 feet, and the cost is about the same as for the drag scraper.

The Fresno scraper has a narrow pan from 3½ to 5 feet long and may be economically used to 200 feet. It requires less time than the two-horse wheeled scraper, but 4 horses are necessary with the larger sizes. The cost ranges from 10 to 15 cents a yard where the haul is from 75 to 150 feet, and the capacity is 60 to 125 cubic yards in a ten-hour day. These machines weigh from 270 to 340 pounds and cost from $30 to $32.

Four-wheeled scrapers are used to a small extent only in sand and gravel work.

CAR LOADERS

Car or wagon loaders, sometimes styled scooped conveyors or elevators, are a comparatively recent development, and their wider use in small sand and gravel pits to load freight cars directly has been recommended as a labor saver and as a means of increasing the production. Car loaders can be used to load either box cars or gondolas, or to load wagons or trucks from the car hopper. They may be also used to load barges from river bars and to unload them, especially when the wharf is 8 to 10 feet above the barge, and the production is not too large.

These devices are of two general kinds, (1) the *endless chain type* and (2) the *scoop-conveyor type.*

The *endless chain loaders* are of a number of different varieties. A desirable type consists of a four-wheeled truck supporting an endless chain excavator equipped with a gear-raising and -lowering mechanism. The weight is from 7,000 to 8,000 pounds, and the buckets are revolved, and the machine propelled by a 10-horsepower gasolene or electric motor. From 20 to 30 buckets, each having a capacity of ½ cubic foot are required, and the loading capacity is said to be one yard per minute under ideal conditions. Two men are required to load with the machine, but it can be done in from one-fifth to one-sixth of the time needed for hand loading. Smaller sizes are made suitable for loading trucks either directly from sand and gravel pits or from stock piles. Sand or gravel can be loaded into cars by this means for about 5 cents a yard, as compared with 15 cents a yard by hand labor. The cost of these machines ranges from $900 to $1,400. A loader of this kind has been used at the J. R. Hime Sand Company's pit near Junction City (Plate IIA), and at the Allon Sand Company's pit near Gaillard.

A somewhat similar loader, mounted on a three-wheeled truck, and of heavy construction suitable for rough work and able to feed automatically into a bank or pile, is also put on the market. The motive power is either electricity or gasolene, and the machine is self-propelled. The capacity of such machines under ideal conditions is said to be about one yard per minute. The weight ranges from 5,000 to 7,000 pounds and from 5 to 8 horsepower are required to operate.

Scoop conveyors are usually of lighter construction than the bucket loaders and consist of a revolving rubber or duck belt from 12 to 16 inches wide, divided into partitions spaced from 10 to 15 inches apart. The length of the conveyor ranges from 14 to 24 feet, and it may be mounted on two wheels. The weight with gasolene motor ranges from 900 to 1,800 pounds, and the horsepower required to drive it ranges from 1½ to 3. The price ranges from $300 to $800. The capacity is said to range from ½ to 1 ton per minute, and one man only is requi ed to load with it. Electric motive power would be much more satisfactory than gasolene if it were available.

The principal difficulty to be considered in the use of mechanical loaders in sand pits is that unless the machine is exceptionally well cared for, it will depreciate rapidly and require frequent repairs, due to sand getting into the machinery. This probably accounts for the many abandoned car-loaders, still in fairly good condition, seen in sand and gravel pits.

POWER SHOVELS

Although few power shovels are used in sand and gravel production in Georgia, they have a wide range of usefulness in other parts of the country, and their more general use in this state is to be hoped for. A small steam shovel operating against a face has proved economical even with common labor as low as 20 cents an hour, and the production under 100 yards a day. With wages at 40 or 50 cents an hour, such machines can operate economically where the production is even lower. Power shovels may be used either to load cars below the face, or, if the face has only a reasonable height, a shovel with a high boom may be used to load wagons or trucks on top of the bank. Some shovels are now manufactured that allow the dipper to be replaced by a grab bucket, or the boom to be replaced by a longer one from which a cable dragline may be operated. This arrangement is desirable in pits having sand and gravel below the ground water level, since after working the material above the water with the shovel dipper, the grab bucket can be used to excavate below water.

Power shovels range in size from 10 tons up to 250 tons, and the buckets may be had from ½ cubic yard up to 10 cubic yards capacity. Their production ranges from 200 to 5,000 cubic yards daily.

Power shovels may either be steam-, electric-, or gasolene-driven. The steam shovel is much more extensively used than either of the other types. The electric shovel, however, is more economical where electric current is available, since it requires less labor and uses power only when the shovel is actually working. The gasolene shovel is desirable in regions where gasolene or kerosene is the most convenient form of fuel, and where water is scarce.

From the standpoint of construction power shovels may be divided as follows:

Types of power shovels

1. Mounted on fixed platform.
2. Mounted on rotating platform, with
   a. Standard gage trucks.
   b. Trucks other than standard gage.
   c. Small, broad-tired wheels.
   d. Caterpillar traction.

Either of the two main types are in use in sand and gravel pits. The fixed-platform type is capable of rotating over arcs of less than 200, and is used in cemented gravel, and in sand and gravel plants where an exceptionally large daily production is necessary. They range from 60 to 150 tons in weight and can produce from 500 to 2,000 cubic yards daily, requiring 3 men for their operation. They generally require considerable time to be moved back to the starting point. The cost of a 107-ton shovel, equipped with a 5-cubic-yard bucket was about $37,000 in 1920.

The smaller, revolving-platform shovels are better suited for small or moderate-sized sand and gravel pits. They usually range from 14 to 70 tons in weight and can produce from 300 to 900 cubic yards in a 10-hour day, the smaller types requiring only one man for their operation. It has been found desirable to use a slightly smaller bucket for a given sized shovel in order that there may be plenty of power, thus avoiding delays due to repairs.

Table showing average capacities and costs of small revolving shovels

Weight in tons	Dipper capacity in cu. yds.	Average daily capacity per 10-hour day	Net cost (1920)	Additional cost for scraper bucket equipment	Additional cost for grab bucket equipment
14	½	300	$8,200	$1,000	$1,000
20	¾	450	8,800	1,400	1,300
24	1	600	10,000	2,000	1,900
32	1¼	750	-------------	2,200	2,100
40	1½	900	12,000	2,400	2,300

In Georgia sand and gravel plants revolving steam shovels are used at the pits of the Atlanta Sand & Supply Company, at Gaillard, at the Muscogee County gravel pit near Columbus (Plate II-B), and at the Altamaha Supply Company's pit near Everett City.

KEYSTONE EXCAVATORS

The Keystone excavator is somewhat akin to power shovels. It consists of frame work or body similar to that of a well drilling machine with a set of jack arms for steadying it while working. The machine is light, auto-tractive, and therefore easily moved from one part of the pit to another. The boom is of light steel and to it is attached the dipper, which may be of three types.

The *skimmer* dipper is shaped like a drag scraper and in operation the boom is dropped close to the ground, and the dipper skims over the top. When loaded the boom is raised, revolved, and dumped.

This dipper permits of shallow and deep cutting and is especially desirable for stripping small thicknesses of overburden or digging thin beds of sand or gravel. (Plate III-A.)

The *draw ditcher scoop* or dipper is suited for trench and ditch work. It is shaped like a steam shovel dipper and has a hinged motion at the end of the boom, but digs toward the machine and below the grade of the wheels. With this dipper clay pockets can be readily removed in a sand deposit, and sand and gravel below the water can be handled by it.

The third type of dipper is similar in appearance and mode of operation to the regular steam shovel type, but is lighter.

POWER SCRAPERS

The use of power scrapers and drag-line cableways, operated at small cost by a hoisting engine, are among the most desirable means of working sand and gravel pits.

ALBRECHT EXCAVATORS

For limited outputs from pits where wagons or trucks are used for direct delivery the Albrecht type of excavator can be used. This machine is generally located above the pit face and operates a scraper bucket by means of a cable hoist, which dumps through a chute into a wagon. This device is said to be able to excavate to a distance of 75 feet below or to its rear, requiring one man to operate the machine and one man to handle the scraper. From 10 to 20 horsepower are needed.

DRAG-LINE CABLEWAYS

For larger outputs, ranging from 200 to 600 yards daily, a permanent mast from 50 to 100 feet high is set up near the bin or beside a railroad spur. The upper end of a steel cableway is attached to the top of the mast and the lower end to a tree, or a "dead man" consisting of a buried log. In dry pits, to insure a wider operating range, the lower end of the cable can be attached to a pulley which can be shifted over a cable stretched between two trees or "dead men." A scoop or bucket, open in front, whose size may range from 0.3 to 3 cubic yards depending on the desired output, is suspended from the cableway by a pulley and operated by a drag-line from a two-drum hoisting engine. The empty bucket slides down the track cable until over the point of excavation, when the drag-line cable is tightened and the track cable slackened, permitting the bucket to drop to the ground. The drag-line is then pulled in toward the bins causing the bucket to pick up a load. When loaded, the track cable is tightened, raising the bucket, and the drag-line is pulled in with the loaded bucket, until over the bins, car, or stock pile, where it is dumped.

A cableway 500 to 700 feet long can excavate over an area of about 3 acres and has the additional advantage of being able to dig to a considerable depth under water. The system is especially well adapted to recovering river-bar sand and gravel. A system of this kind was formerly in operation on Bull Creek, near Columbus, Ga., and at Augusta, Ga.

Drag-line cableways have a wide range of usefulness, are efficient, simple in their construction, and have a low cost. Only 4 or 5 men are required for a daily production of 400 yards. Their capacity depends on the length of the span, the depth of the pit, the size and character of the bucket, the character of the material, and the efficiency of the operator. They are more efficient for wet excavation than in dry pits.

Table showing average requirements, capacities, and cost of drag-line scrapers

Bucket capacity in cu. yds.	Double-driven skeleton hoisting engine	Diameter of front drum in inches	Production in 10 hours, cu. yds.	Approximate total cost of installation
¾	8¼ x 10 or equivalent	20	125	$8,000
1	9 x 10 " "	24	225	10,000
1½	10 x 12 " "	26	400	13,000

A drag-scraper bucket of ¾ to 1 cubic yard capacity costs about $750.00.

In Georgia a simpler and less expensive form of the drag-line system is in use at Rutledge and Chestnut's plant, on Bull Creek, near Columbus, and at the plant of the J. R. Hime Sand Company, near Junction City. (Plate III-B). No cableway is used in this variation, the drag bucket being simply pulled backwards and forward over the sand. In order to elevate the bucket it is necessary to construct a wooden incline up which the loaded bucket is pulled to a loading platform or screening plant which may be from 20 to 30 feet high. Where the sand pit has a high face that has already been opened the loading platform or screen can be built in the worked-out portion of the pit in front of the face, so that the top of this structure will be level with the natural top of the sand and the loaded drag-bucket dumped at this point. Besides having fewer parts to get out of order, this system only costs from $2,500 to $3,000 to install, depending on the equipment.

Drag-line cableways can be used to advantage where a greater reach is necessary than that of a power shovel or a boom drag-line excavator. They permit digging over larger areas and to much greater depths. Production is not so great as with the other two methods, since the digging, conveying, and elevating is all done by one machine. The cost, however, is probably less than that of doing the same amount of work by other methods, and ranges from 3 to 15 cents a yard. Steam-, electric-, or gasolene-driven drag-lines are in use as well as many variations depending upon local conditions.

The system has the disadvantage, however, of traveling empty one-half the time. This feature may, in a measure, be remedied by operating two scrapers at a slight additional cost; one scraper would then be digging while the other is dumping. Drag-line scrapers frequently leave the pit in bad condition, with steep grades, making a future change to steam shovel operation, when it is desired to increase the production, very expensive. Scrapers can not dig to such great depths under water as can drag-line dredges.

DERRICK SCRAPERS

Quite generally scrapers are suspended and operated from the boom of a locomotive crane or steam shovel or from a derrick car. (Plate IV-A.) With such an arrangement the system is more flexible and portable than the cable drag-line system, but the span and range of operation, and the depth to which digging is possible, is not so great. Digging can be carried on with equal ease in water, but frequent moving is usually necessary, especially with short booms. The boom may be from 30 to 140 feet in length, carrying a bucket of from ½- to 5-cubic-yards capacity. The digging radius depends on the length of the boom and the angle at which it is working and rarely extends more than 10 or 15 feet beyond the end of the boom. The depth to which such an excavator can dig depends on the skill of the operator and the character of the material handled and usually ranges from a few feet to 40 feet. They may be mounted on standard gage trucks, caterpillar trucks, or skids and rollers. Their production ranges, on the average, from 200 to 1,000 yards per 10-hour day, depending entirely on local conditions and the size of the bucket used. Several companies build steam shovels with interchangeable shovel and drag-line booms, the additional equipment costing from $1,000 to $2,500. In this case the same power plant used in shovel work must be used for drag-line work. Before ordering such equipment it is best to be sure that efficient results can be obtained from such an arrangement.

POWER-OPERATED GRAB BUCKETS

Buckets of the clam-shell or orange-peel type are used in excavating and loading sand directly from the river or pit into cars, bins, or elevating devices, and in unloading barges and transferring the material to cars, hoppers, or stock piles. Various types of machines have been developed to operate such buckets. Among these are locomotive cranes, travelling towers, movable bridges, telpher systems, lighters, dredges, and derricks of either the stiff-leg, travelling, or skid-excavator types. The use of buckets is rapidly becoming general throughout the country for reclaiming and storing material even when the quantity handled is as little as 2,500 tons a year. They possess the additional advantages of being able to operate with equal ease both above and below the water level and of taking the place of the elevating conveyor systems necessary if power shovels are used in pits where the material must be washed and screened. From one to two round trips per minute can be made with the bucket, but the production will largely depend on the capacity of the bucket.

Locomotive cranes.—Locomotive cranes are used in Georgia by the Allon Sand Company at Gaillard, and by the Kirkpatrick Sand and Cement Company and the Central of Georgia Sand Company at Howard. Their types and specifications closely follow those of the power shovel, and in fact some of the steam shovel companies put on the market machines with interchangeable booms. Locomotive cranes have a much wider range of activity than power shovels, especially in pits with high faces, and if the boom is high enough the sand can be delivered directly to the top of the washing plant without the use of elevator conveyors.

Traveling derricks.—The most frequent application of bucket excavators in sand and gravel pits is some form of travelling derrick (see Plate IV-B). These usually have an A-frame beneath which a mast is mounted on a platform and capable of swinging about on a track over an arc of almost 180°. They are moved either on rails or on skids. Those moved on skids are called *skid excavators*. The range and depth of digging depends on the length of the boom, the power, and the skill of the operator. The bucket is operated by cables passing over the top of the mast from the drums located behind the frame. The horse-power capacity required ranges from 15 to 50 and the production from 200 to 500 cubic yards per 10-hour day. The material can be loaded directly on cars or delivered to the washing plant.

Travelling towers.—At a few of the largest plants travelling towers have been erected for unloading sand and gravel from barges. Their capacity is very high and their range large.

Stiff-leg derricks.—A single mast or tower made of wood or steel may be erected at the unloading point of sand barges. A revolving boom similar to that in the travelling derrick excavator, and constructed of wood or steel, has the bucket suspended from it. The horsepower required is from 20 to 30, and the cost of erection and equipment around $2,500. Stiff-leg derricks of wood are fairly common in sand pits. At Rome an unloading arrangement of this kind is used by the Rome Sand and Gravel Company to unload sand from scows.

The stiff-leg American derrick is of steel and consists of a tall vertical mast from which a revolving carrier projects horizontally a considerable distance. The bucket is suspended from this and may be moved and operated at any point along it.

Cableway dredges.—In some parts of the country, particularly in Nebraska,[1] sand is dredged from under water by means of a clam-shell bucket or dredge which runs along a cableway. A double cable from 300 to 350 feet long is suspended between two towers, which are from 30 to 50 feet high and from 180 to 250 feet apart. A clam-shell bucket is attached to a clam-head, which in turn is attached to a carrier running along the cableway. The construction is very heavy

---

1 Condra, G. E., The sand and gravel resources and industries of Nebraska: Nebraska Geol. Survey, Vol. 4, pt. 1, pp. 65-69.

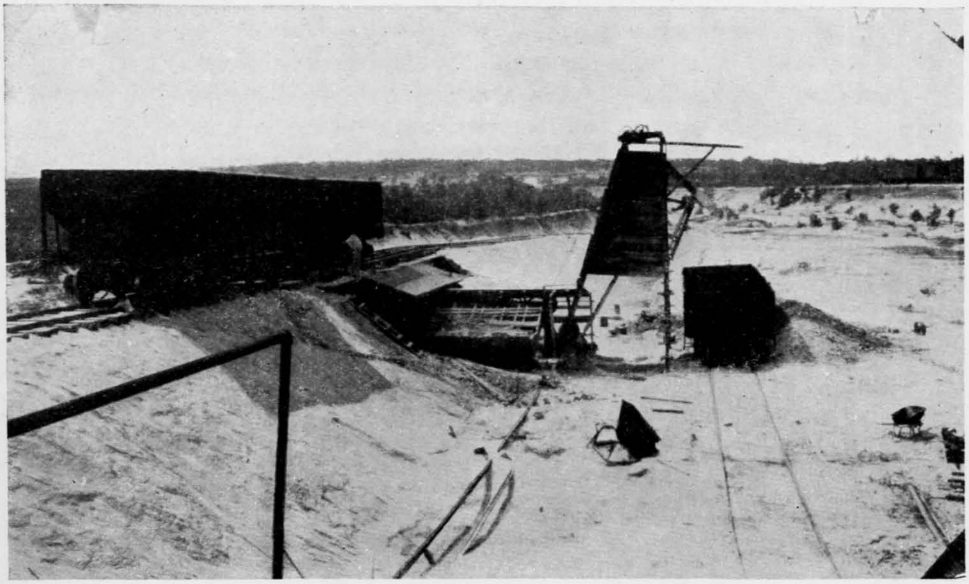
the bucket weighing about 3,000 pounds and the carrier 1,500 pounds. The capacity of the bucket averages from one to two tons of sand or gravel. In operation the open dredge descends by gravity along the cableway to the water and sand, and the clam shells are closed on a load as they are raised. The dredge is first raised to the carrier and is then drawn to the tower where it is dumped into a car or hopper. The dredge makes a trip usually in about 80 seconds and a car can be loaded easily in an hour.

This method is economical and affords a means of producing sand from beneath water, either in natural lakes or where the ground water is soon reached. The method is superior to pumping, since the dredge can be operated to depths of 30 to 80 feet. A selection of sand is impossible with the dredge, and when a portion of the deposit is worked out the cableway must be moved.

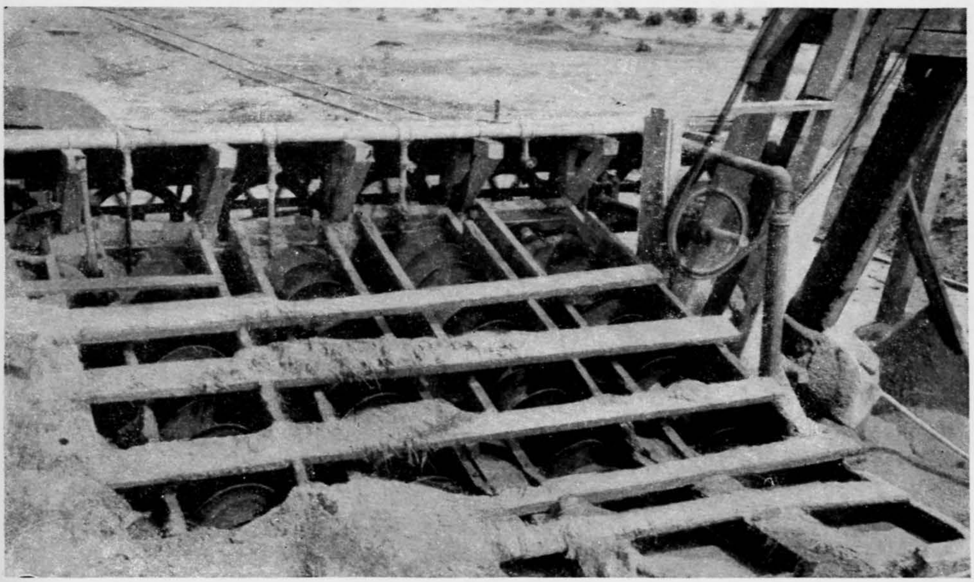
Floating dredges.—The system is capable of producing large quantities of sand and is more suitable for use in deeper water where the centrifugal dredge can not be efficiently operated, or where the sand and gravel is too hard-packed to be handled by the pump. It can dredge much deeper than most ladder dredges and in this respect is more suitable under certain conditions. The bucket is suspended from a revolving boom attached to the stern of the scow or barge. The construction is similar to that used in derricks on land. The capacity would range from 15 to 800 cubic yards per hour with buckets of from ¼ cubic yard to 13 cubic yards capacities. A dredge of this type is used by the General Building Supply Company, on Savannah River at Savannah.

Buckets.—The clam-shell and the orange-peel are the two general types of buckets used. The clam-shell bucket ranges in capacity from ¼ cubic yard to 13 cubic yards and from ½ ton to 13 tons in weight.

The orange-peel bucket is not so widely used as the clam-shell bucket, nor is it so well adapted to digging hard-packed sand or gravel. Its size ranges from 2 cubic feet to 10 cubic yards. The cost of either type of bucket of one or two cubic yards capacity is from $700 to $850.



A. SAND-WASHING PLANT, KIRKPATRICK SAND & CEMENT COMPANY, 2 MILES WEST OF HOWARD, TAYLOR COUNTY



B. SCREW WASHERS, KIRKPATRICK SAND & CEMENT COMPANY, 2 MILES WEST OF HOWARD, TAYLOR COUNTY

CENTRIFUGAL PUMPS

For the production of sand from the bed of streams, or from artificial ponds, centrifugal pumps are the most economical devices and have the largest capacity. In Georgia, centrifugal pumps are used on Ocmulgee River at Dames Ferry and Macon; on Peachtree Creek and South River, near Atlanta; on Savannah River at Augusta and Savannah; in pumping gravel from an artificial pond at Augusta (Plate V-A); and for temporary use on one or two smaller streams.

Centrifugal sand and gravel pumps usually range in diameter from 4 to 18 inches, although pumps up to 48 inches in diameter have been used on Mississippi River for channel-deepening purposes. The capacity of sand pumps is said to range from 12 to 600 cubic yards per hour, depending on their size and the percentage of solids in the liquid. (Fig. 6.) The horsepower required to operate them ranges from 6 to 300. Centrifugal pumps or hydraulic suction dredges are superior to steam shovels and dipper or elevator dredges, in that they not only pick up the material, but deliver it to any desired point within a reasonable distance of the dredging location. Such pumps will

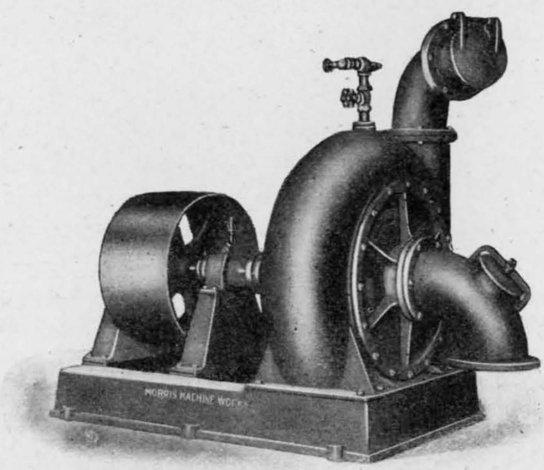


Fig. 6. Six-inch centrifugal sand pump. (Morris Machine Works.)

handle most types of submerged sand and gravel, although where the material is hard-packed it is necessary to cut it up first with a revolving cutter or by a water-jet system. Ordinarily, however, no such arrangement is needed.

Usually a pump can handle a liquid having from 10 to 15 per cent of solid material in suspension, although the character of the sand or gravel will considerably alter this figure. In some places as high as 40 per cent solids has been handled. The most efficient proportion of sand to water usually depends on local conditions, and careful experimentation will generally determine this ratio. Due to the nature of the work done by pumps of this type, the efficiency is comparatively low, ranging from 40 to 50 per cent. The constant passage of sand and gravel through the pump cuts out the manganese linings requiring their replacement in the larger pumps every month or two, but in the smaller machines their life is much longer. The size of the gravel which can pass the pump openings ranges from a screen, to prevent the entrance of sizes larger than the coarsest grade for commercial use. Centrifugal pumps may be operated in water ranging from 2 to 30 feet in depth. The most desirable depth for the efficient operation of the pump ranges from 4 to 7 feet. The deeper the water the more power is required to suck the sand through the intake pipe, consequently for dredging in deep water grab buckets are more economical. There should be at least 4 feet of sand in the stream bed where recovery by pumping is planned. Frequently great inconvenience is caused by roots and fragments of wood clogging the intake, particularly with 4-inch pumps, so that the suction must be reduced until the debris frees itself, or the pump may have to be stopped entirely and the intake raised and freed of rubbish by hand. On larger streams such as Ocmulgee and Savannah rivers this trouble is not so common, but in the smaller creeks it is likely to cause considerable delay and even prohibit the use of a pump.

Centrifugal pumps may be located to deliver their product directly into railroad cars, as is the case at Dames Ferry and Macon on Ocmulgee River, into bins, or into hoppers, from which it can pass to a grading plant or to a bucket elevator. If delivery is made direct to the shore by the pump considerable energy will be required to overcome the friction of the delivery pipe, especially if it is very long. The maximum economic length of the delivery pipe in Georgia, for 6-inch pumps, is about 300 feet. Each additional 20 feet reduces the production of the pump half a car daily. With larger pumps longer deliveries are possible. It is economy to deliver the sand direct to cars, provided the track is on a firm foundation to prevent the overflow undermining it.

Centrifugal pumps are desirable not only because they can produce immense quantities of sand but because they furnish a thoroughly washed product, and also because they afford a means of economical sand production in pits from below the water level. Their initial cost is low, and the expense of producing sand by this method is, in many cases, actually lower than in any other system. They are not so cumbersome as are other methods of recovering sand from water, and since they can be made for smaller capacities than other systems, they enable a small producer to operate at little cost.

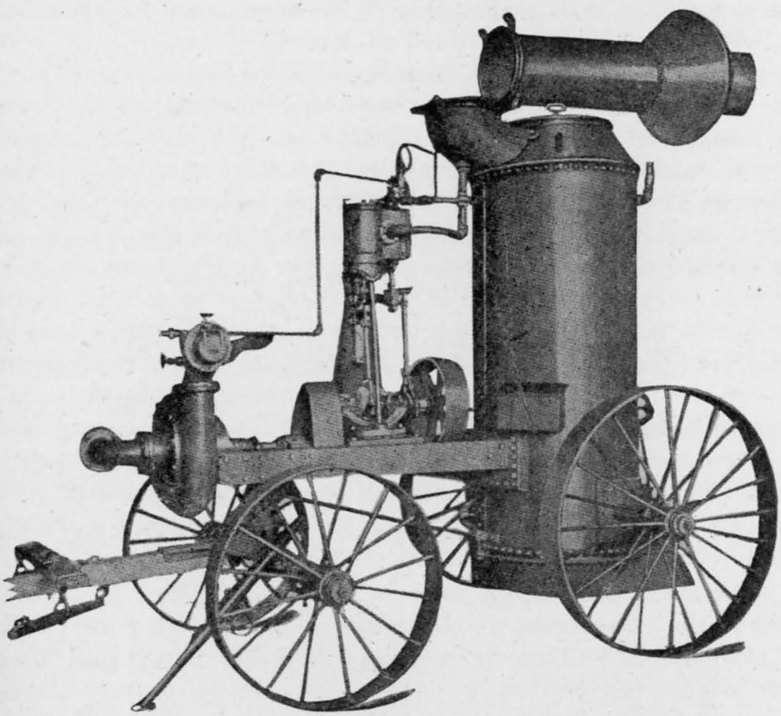


Fig. 7. Portable centrifugal sand pump, (Erie Pump & Engine Works.)

For small production, especially in road and bridge building work, 6-inch pumps, driven by gasolene or steam, have been used. In many cases their work has not been found to be as satisfactory as was expected, usually because the power requirements were underestimated and because twigs and debris so quickly clogged the intake, but it is believed that portable pumps and power outfits similar to that pictured (Fig. 7) should prove serviceable, especially in the northern part of Georgia where sand and gravel deposits are generally confined to the beds of creeks and rivers. Practical sand and gravel men say it is almost impossible to use a 4-inch pump, due to debris preventing the entrance of the sand. In the case of gasolene-operated pumps they should be belt-driven rather than directly connected to the engine.

In some pits, where the ground water is near the surface and where the sand is loosened hydraulically, an artificial pond or sump is created in the center of the pit, and a centrifugal pump installed to suck up the sand and raise it to the top of the screening plant or to the washers, screens, or bins. This system is used in connection with hydraulic jetting in sandstone quarries in Pennsylvania and West Virginia, where the rock is easily loosened. In Georgia, the Georgia Sand and Gravel Company, at Augusta, uses a 4-inch pump to raise the material from the pit, which is full of water due to the high water table, to the top of the screening plant 24 feet above.

Table giving description and average capacity of centrifugal sand pumps

Size of pump in inches	Cubic yards material handled per hour with 10 per cent of solids	Horse-power required for each 10 feet elevation	Will pass solids: Diameter in inches	Floor space required in inches	Max. head, feet.	Max. R.P.M.	Max. H. P.	Weight in pounds.
4	14	4	2½	40 x 31	35	550	15	1,200
6	30	8	4	68 x 40	28	500	27	2,500
8	60	15	6	72 x 48	40	350	65	5,000
10	90	25	8	94 x 54	35	325	65	7,000
12	125	30	10	114 x 66	35	250	100	10,000
15	210	50	10	154 x 78	50	250	180	18,000
18	300	70	10	160 x 80	55	250	208	20,000
20	360	80	10	----------	------	--------	------	--------
24	480	100	10	----------	------	--------	------	--------
32	900	200	10	----------	------	--------	------	--------
36	1,140	250	12	----------	------	--------	------	--------
48	2,040	450	12	----------	------	--------	------	--------

CENTRIFUGAL DREDGES

For the production of immense quantities of river sand and gravel large, floating, centrifugal-pump dredges are used. These have been developed to a considerable degree on Mississippi and Ohio rivers. In general they consist of wooden or steel hulls, of light draft but heavy construction, and housed over. The dredging end has an A-frame projecting beyond the hull. The dredging end is usually downstream when working. The centrifugal pump has a steel runner of four curved blades, closely fitted to the casing to prevent leakage back. A large space is provided in the discharge volute due to the wearing action of the sand and gravel. No sharp bends are allowed and all passages in the pump must be larger than those in the suction pipe to prevent obstruction.

Stirring devices, consisting usually of water jets, agitate the sand and permit it to be easily sucked up. The discharge pipe delivers the material into a barge or scow which is fitted with a screen to keep out large stones and debris. The largest dredges have two engines, one on each side, usually steam-driven, and either vertical or horizontal, to permit loading two barges at once. The man feeding the suction head is situated so he can see the discharge mixture and regulate the depth of the pump thereby.

Although the cost of reclaiming sand and gravel by this method is small, averaging from 10 to 30 cents a yard in 1919, the necessity of rehandling from the barges to cars as well as the lack of convenient storage facilities, adds greatly to the marketing cost.

LADDER DREDGES

When a large production is necessary in rivers where the sand and gravel is so hard-caked that it will not readily flow into the suction head of centrifugal pumps, ladder or belt-bucket dredges are used. This type is not at present operated in Georgia, although the Rome Sand and Gravel Company formerly used one in dredging on Ostanaula River, at Rome. They are used mostly on upper Ohio River and on Allegheny River near Pittsburgh, at Buffalo, and at Philadelphia. A large dredge has recently been placed in operation on Chesapeake Bay near Baltimore. Although a tremendous production is possible with this type of dredge it can be used only in comparatively shallow water.

The hull is of heavy wood or steel construction and of the square barge type with light draft. The dredging apparatus is placed either at the end or on the side. The buckets must be of extremely heavy construction and consist of steel plates riveted together by a chain formed of steel-bar links so as to permit working around tumblers. Roller bearings are placed along the ladder at intervals to insure uniform support. The material is dumped at the top tumbler on to moving screens, the sand passing in one direction and the gravel in the other, and the empty buckets returning unsupported. The boiler and engine equipment must be sufficient to revolve the buckets, raise and lower dredging end of ladder, operate capstans and siphons, and possibly propel the dredge.

The buckets used on ladder dredges range in capacity from 1 to 14 cubic feet and almost any production desired can be obtained. The dredges may simply dig the sand and gravel, or, as in more recent types, the barge may be equipped with complete washing and screening apparatus. Gillette[1] gives an average cost of 23 cents a yard in 1918 to produce sand and gravel by this method. It is certainly inferior to drag-line and pumping systems, and its use should only be considered where compact, indurated material is concerned.

HYDRAULICKING

A method of loading sand, not generally used in the East, is to direct a strong jet of water against the sand-pit face, and carry the loosened sand and water in troughs supported by light trestle work direct to the car, plant, or to a sump from which it is delivered by a centrifugal pump.

At Gaillard, Georgia (see p. —), the Atlanta Sand and Supply Company produces sand from one of their pits hydraulically. (Plate V-B.) In Pennsylvania, in some of the glass sandstone quarries, the sandstone is friable enough to be loosened in this way.[2] The water carries the sand down to a central sump, or pond, from which it is delivered to the washing, screening, and drying plant by a 4- or 6-inch centrifugal pump. Sand and gravel is produced by this system at many places on the Pacific coast. The hydraulic method insures economical production of washed sand, since the run-off water from

1 Gillette, H. P., Handbook of cost data, 1919.
2 Boehringer, R. A., Hydraulic sand-mining plant: Eng. News, Vol. 72 pp. 372-374, 1914.

the car or bin carries with it considerable clay and foreign matter. It is not to be recommended, however, where the water supply is small or where it is required to be raised a great distance to the face. The grade necessary to carry the sand from the face to the point of delivery, generally from 6 to 15 per cent, is such that unless the sand deposit is of great thickness, or unless it slopes down toward the working face, a height equal to the thickness of the deposit will soon be necessary to transport the water and sand to the cars or bins. Six volumes of water to one of sand, five volumes of water to one of gravel, and four volumes of water to one of a mixture of sand and gravel, are required in the hydraulic system.

Deposits containing from 20 to 25 per cent waste were reclaimed by this method at a cost of 15 cents a yard in 1915, on the Pacific coast. Plants producing from 300 to 2,500 yards daily were able to operate at a cost per yard, including recovery and treatment, of 8 to 15 cents in 1915. A Seattle sand plant used two hydraulic giants delivering water at the face at 90 pounds pressure. A continuous bucket elevator carried the sand to the top of the screening plant. Six men were employed and 800 yards were produced in 8 hours.

Hydraulic jets have also been used in stripping sand or gravel deposits. For this purpose ample water, good grades, and drainage are necessary. For clay overburden more water, higher pressure, and steeper grades are required than for loam. Usually the amount of water is more important than the pressure. In the case of a deposit described by W. H. Wilms[1], soft loam needed 8 per cent grades and 1,500 gallons of water at 75 pounds pressure for each cubic yard removed. An average cost of 6 cents a yard is given for hydraulic stripping.

PREPARATION OF SAND FOR THE MARKET

Very little Georgia sand or gravel is washed or screened before shipment. Most of it is loaded directly from the bank into cars or pumped into cars or bins from streams. This is undoubtedly the cheapest way to handle sand, but in many cases it is certainly not the most economical. Although the clay content may not always detract from the value of a sand so far as producing concrete is concerned, there is a growing demand for clean sand. Since screening

1 Development of sand and gravel deposits: Eng. News, Vol. 72, pp. 908-911, 1914.

is usually a process requiring little additional outlay, if the sand is washed, the division of the product into several uniform grades is especially desirable. A much higher price can be obtained for the coarser, cleaner grades, so that the additional expense of treatment is well repaid. In installing washing and screening plants the future growth of the business should be considered, and the plant constructed to allow of ready additions or alterations. It should also be borne in mind that the most ecomonical operation of such plants depends largely on a steady flow of material through them. Intermittent deliveries of sand to the plant are costly and may in the end consume the profits. It is also absolutely essential, if the plant is to be a success, that the operator be thoroughly acquainted with the demand for its products as well as their character and amount, before deciding how much money to spend on a plant. There have been a number of failures in Georgia due to incorrectly estimating the supply and demand and buying too much equipment. A knowledge of the market for the different grades is also essential in designing the plant, in order that there will be no wastage of any of the sizes, particularly the finer-grained sizes.

WASHING AND SIZING

Aside from the natural washing sand receives when pumped from streams, only two plants in Georgia wash their product. (Plates VI-A, VII-A.) Much of Georgia sand is naturally clean, and washing, for most purposes, might not improve it, except that the water would aid screening.

The usual principle[1] employed in washing and sizing sand or gravel is to conduct the material to the top of a frame-work structure or tower and allow it to work its way downward by gravity through revolving screens of different sizes which separates it into the various grades desired and direct its course to the several bins, cars, or pits. A two- to four-inch stream of water is raised to the top of the tower and is jetted on the sand as it passes over the screens. (See Fig. 8 and Plate VI-B.) About 60 per cent of the sand and water delivered to the receiving hopper is water. It usually requires about one gallon of water per minute per cubic yard of material handled.

1 Wilms, W. H., Operation of sand and gravel plants: Eng. News, Vol. 72, pp. 962-966, 1914.

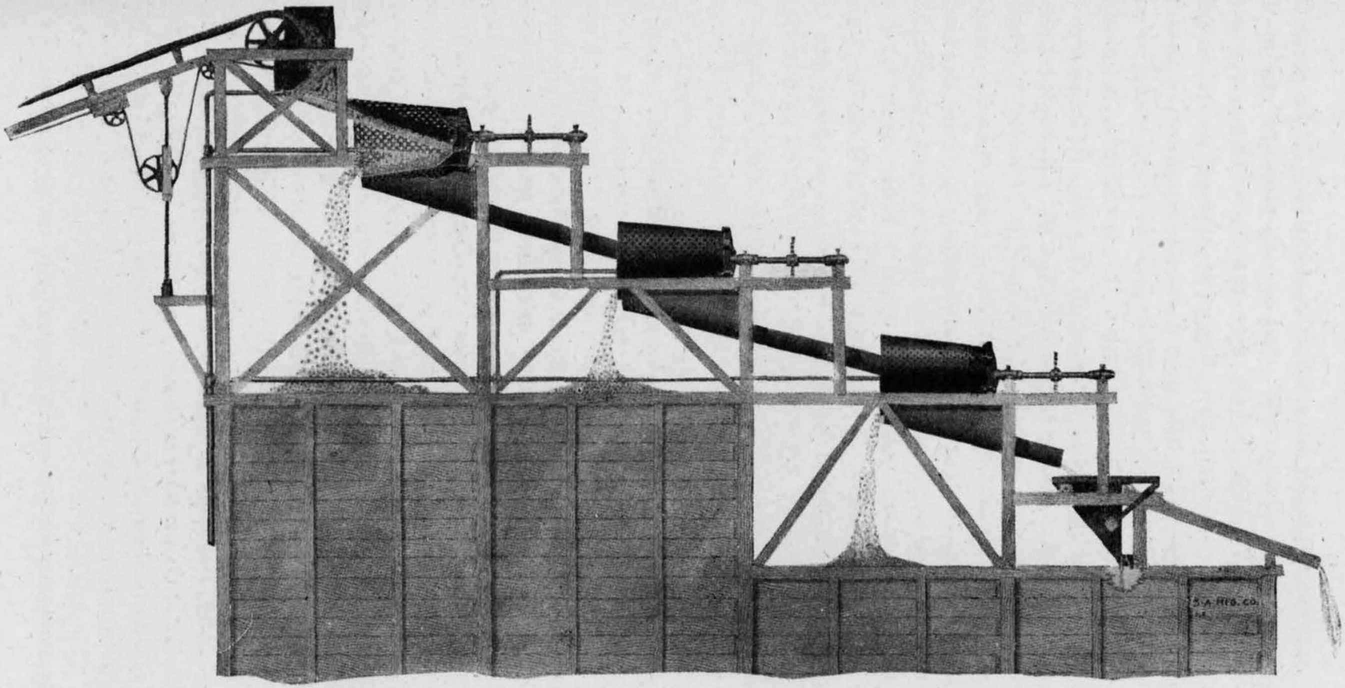


Fig. 8. General Arrangement of Washing and Screening Plant, Using Gilbert Screens.
(Stephens-Adamson Company)

The essential idea in washing is to agitate the material sufficiently to reduce the lumps of clay, so that they can be carried away in the wash water, leaving the sand and gravel behind. Such agitation should remove films of clay from the individual sand grains or pebbles. In screening or sizing, the raw material should pass first to the coarsest screen, since here the largest proportion of material will be removed, and the construction of this screen is better able to stand the strain and wear of the entire product passing over it. The screens of the next smaller sizes should follow, so that the finest and lighest screen will have the least amount of material to handle. Better screening efficiency is also obtained in this way, since the screens are not overcrowded. Some clayey materials require a preliminary washing before going to the screens. This is usually accomplished by scrubbers or screen washers.

No two sand pits afford exactly similar conditions, hence it is necessary to carefully study local conditions before deciding upon a design for a plant.

Screens.—Screens may be either *conical* or *cylindrical.* the conical type, however, is preferable. Conical screens may be either *horizontal* or *inclined.*

In the *horizontal* type the material is fed from the spout or trough into the interior, or smaller end of the screen and works down the cone slope against water jets toward the next higher screen until it reaches the larger end of the screen where it drops to a trough or launder and is carried downward to the next lower screen. Each screen is rotated on a separate shaft, the revolutions being about 12 to 14 per minute for smaller screens and from 9 to 11 for larger sizes. Since the material works against a stream of water, better separation of clay and other impurities is obtained in this type of screen. The capacity is also said to be greater than one in which water and sand flow in the same direction. A separate drive for each screen shaft, however, requires the use of more power. It is said that screens of this type are in use in 90 per cent of the gravel washing plants in the United States.

Inclined conical screens are also widely used in sand and gravel plants. The angle of inclination should be such as to insure the ready movement of the material through the system and at the same time not allow so rapid a progress as to prevent thorough washing and screening. This angle will vary with different types of material and different capacities but in general it is about 1½ inches per foot. The sand is fed to the upper, or larger end of the screen and works downward, passing into the next lower screen. All the screens are generally mounted on the same continuous shaft which in operation makes 10 to 12 revolutions per minute.

Cylindrical screens are used in some of the older plants, but they are not so efficient as the inclined conical type, except possibly where the material is screened dry. They frequently consist of two screens one within the other. Screens of this type were used at the plant of the Rome Sand and Gravel Company at Rome.

Shaking screens are sometimes used but they are advised against, since the constant agitation quickly wears them out. Screen apertures should preferably be round, since stones will not plug up round holes as readily as square holes. Any number of screens may be used, depending on the number of grades of material desired. If three screens are employed they are usually 1½-inch, ¾-inch, and ¼-inch.

Separators.—Sand separators are usually of two types, (1) *valved* and (2) *tipping*. The valved or stationary separators are usually of conical- or wedge-shaped construction with the smallest end downward and are most desirable in large plants. The sand accumulates in the tank until its weight is sufficient to overcome the counterweight which operates to hold a valve tightly seated over the opening in the bottom, when the valve opens and the sand runs out into cars or bins until equilibrium is restored and the valve closes. At some places the valves are opened by a man at the "top."

Tipping separators are of wood or steel construction, either wedge-shaped or square, and generally balanced on knife edges and held upright, when empty or only partially filled, by a counterweight. After a certain weight of sand is in the tank, it becomes overbalanced and tips causing the sand to dump out into cars or bins. Some small plants have two sand separators, the coarse sand collecting in one, and the fine sand passing over the top with the overflow into another separator where it collects, and the silt and mud passing off into launders with the wash water.

Screw washers.—Crushed sandstone for glass-making purposes is generally washed in sand-washing screens. The plant of the Fitzpatrick Sand and Cement Company at Howard, Ga., uses five washing screws 12½ feet long for washing its product. (Plate VII-B). Plants producing concrete aggregate in other states use this type of washer to some extent. The usual type of screw washer consists of a wooden trough from 8 to 12 feet long and from 16 to 24 inches wide, inclined from 18° to 20° from the horizontal (31 to 34 per cent), and containing a cast-iron rotating screw conveyor with wide blades. Sand to be washed is fed in at the lower end of the washer and water enters at the top. The rotating screw forces the sand upward against the stream of water which cleanses it of clay and silt and carries away those materials in suspension. The screens may be set up in batteries of two, three, four, five, and six washers each, arranged either parallel to each other, or in tandem. When arranged in parallel the sand leaving the top of one washer is delivered at the bottom of the next parallel washer. When arranged in tandem the sand falls directly from the top of one washer to the bottom of the one above. Screw washers can handle from 10 to 20 tons of sand each per 10-hour day, and require about one horsepower for the operation of each screw, which cost from $100 to $175 each. Washers of this type are desirable in small plants, and they are considered more effective in freeing the grain from adhering clay than ordinary revolving screens.

Scrubbers.—Where a gravel or sand contains a large percentage of clay, it may be removed before or during screening by a preliminary washing called scrubbing. The preliminary washing is generally accomplished by passing the material through a solid cylindrical shell with internal retaining rings which divide it into compartments. These retaining rings slow up the passage of the material through the cylinders and allow lifting vanes, which project inward a few inches, to raise the sand and gravel and drop it into water, thus washing it and carrying it forward to the opening through which it passes to the screens. For scrubbing a small scrubber of one compartment is attached to the end of each screen at which the sand is introduced.

CRUSHING METHODS

When sandstone or quartzite is quarried for glass manufacture it is necessary to crush the hard rock into the component grains. Some gravel plants use crushing machinery to reduce oversize pebbles and boulders to commercial sizes. No sandstone is crushed in Georgia now, but in 1915 a few carloads of sandstone from Rocky Face, in Walker County, were crushed and shipped. In Pennsylvania, where great quantities of Oriskany sandstone and Pottsville conglomerate are quarried for glass making; in West Virginia, where the Oriskany sandstone is quarried; and in Missouri, where the Dakota sandstone is used, most of the product is put through various types of crushing devices for its reduction to grain size. To a lesser extent crushing is practiced in a few glass factories to reduce sand to a finer-grained product than the form in which it is mined. Crushing of silica rock, either as sandstone, quartzite, ganister, or incoherent sand, is necessary in the manufacture of silica and sand-lime brick. In Georgia, sand for the manufacture of sand-lime brick is crushed at the Tift Silica Brick Company's plant at Albany.

The following types of machines are in general use in washing and grinding silica rock and sand:

- Crushers
  - Jaw crushers
    - Blake type
    - Gates type
  - Gyratory crushers
- Chaser mills
- Grinding pans
- Pulverizers and disintegrators
- Tube mills
- Ball mills

Crushers.—Crushers are used for crushing the large blocks of sandstone as they come from the quarry. *Jaw crushers* consist of the Blake type, which is the one most generally used in sand crushing work, and the Gates type. A jaw crusher having a 20 x 10-inch opening can handle from 15 to 25 tons of sandstone daily, crushing it to a diameter of 3 inches. Such a machine requires 15 to 25 horsepower to operate it and costs about $600.

Gyratory crushers consist of a central tapering spindle which rotates on an eccentric and grinds the rock between it and the outer circular walls of the machine. These crushers have much larger capacities than the jaw crushers, and a few are in use in sandstone quarries and in gravel plants for the reduction of oversize boulders. Gyratory crushers 4 x 15 inches in size of receiving opening, have a daily capacity of from 20 to 40 tons, requiring from 3 to 4 horsepower and costing about $700.

Chaser mills and grinding pans.—To further reduce the sandstone after it has come from the crushers, or to handle directly the smaller material from the quarry that has passed through the grizzly, chaser mills and grinding pans are used. These machines may be used either to grind the rock with the addition of water or to grind it dry. Wet grinding machines consist of fixed circular steel pans, ranging from 6 to 9 feet in diameter, in which two heavy steel rollers, mounted on a horizontal shaft, revolve. The rollers in a 9-foot pan have 12 inches rolling surface and weigh from 5,000 to 6,000 pounds each. The ground material leaves the pan through screens on opposite sides. A 9-foot pan will handle from 100 to 250 tons daily, depending on the friability of the sandstone. About 35 horsepower is required to operate a pan of this type, and the cost ranges from $1,200 to $1,500. The dry-grinding pans are used in plants where the sand is shipped without washing. The rolls of these machines turn on a horizontal axis and the pan also rotates.

Tube mills.—Tube mills are used in grinding sand to smaller sizes for sand-lime brick manufacture, and in grinding quartz and quartzite to fine grains, and even powders, for use in the arts and industries. They are cylindrical in shape, built of heavy boiler-plate steel, and are revolved on a horizontal shaft. They range from 3½ to 6 feet in diameter and from 14 to 22 feet in length. Enough steel or flint balls, 2 to 3 inches in diameter, are put into the mill to fill it one-third; and the sand, which is introduced through an opening at one end with the lime or other materials used in the manufacture of the product, leaves the mill at the other end. A 6-foot mill makes 25 revolutions per minute, and has an average capacity of from 40 to 60 tons daily.

DRYERS

Sand used in locomotives is always dried, and at many places the sand used in the manufacture of glass and sand-lime brick is also dried. In Georgia the various railroads have usually installed small conical dryers at sand pits along their line for preparing the sand, or in some cases have built large dryers at their main shop.

The usual type of small dryer consists of a stove around which cylindrical or conical sheathing of sheet iron is built forming a space holding from one to two cubic yards of sand between the sheathing and the stove. The lower part of this container is perforated with holes one inch in diameter and three inches apart, so that the sand as it dries trickles out through the holes into a bin or other receptacles. In warm, dry weather from 30 to 40 minutes are required to dry a yard of sand.

The general system in use where large quantities of sand are dried is to construct a frame house of two or three stories. The stoves are placed in the first story and drums, two feet in diameter, are placed around them, which extend upward through the roof, but are much smaller in the upper stories. Around the stoves sheet-iron jackets are placed which expand at their upper ends permitting the sand to settle between them and the stove. The jackets are perforated at their base to allow the dried sand to escape into chutes or bins.

The wet or green sand is discharged from cars into the second story from which it works its way downward around the stoves to the first story. From here it may be delivered directly to cars or locomotives or elevated to a third story where it can be stored.

There are several types of dryers for glass sand in use, but the steam dryer is the most modern and efficient. The sand is discharged into horizontal steam pipes arranged in tiers in the dryers.[1]

Direct heat dryers are also used. This type consists of a rotating cylinder, heated by gas, oil, or coal fuel, into which the wet sand is fed at one end and discharged dry at the other end.

STORAGE

In plants producing washed sand and gravel it is desirable, and in fact profitable, to have surplus storage facilities, which can be drawn upon when the plant is temporarily shut down for repairs, or in winter, and in which the various sized products may accumulate in dull seasons or when the demand for certain grades is temporarily slack. For example, a large order may be received for gravel, but there may be no ready sale for the sand. In order to avoid sacrificing the sand at an unprofitable figure, which would be necessary if there was no place to store it, it can be put into bins or stock piles for use a few days later when the demand increases.

Sand and gravel for structural purposes can be piled in large stock piles in the summer for winter use without harming the sand. This is the most general way of storing the material. The piles can be built up by transporting the sand over belt conveyors supported on a wooden or steel framewo k and, in the case of the larger plants, distributed over a large area from a wooden or steel trestle. Loading is accomplished usually by bucket and crane or stiff-leg derrick. Many

1 Fettke, C. R., Glass manufacture and the glass sand industry of Pennsylvania: Pennsylvania Geol. Survey, Rept. XII, 1919.

of the larger plants have storage bins of steel or wood of from 200 to 600 cubic yards capacity, the sand being delivered to cars by gravity. (Plate VIII-A.) These bins prevent waste and afford more economical means of handling, but they are not necessary. Plants producing locomotive sand require inside storage, since this type of sand must be kept dry.

PROSPECTING FOR SAND AND GRAVEL

For convenience we may describe the prospecting of sand and gravel deposits under three main headings:

1. Stream deposits.
2. Bank deposits.
3. Sandstone deposits.

STREAM DEPOSITS

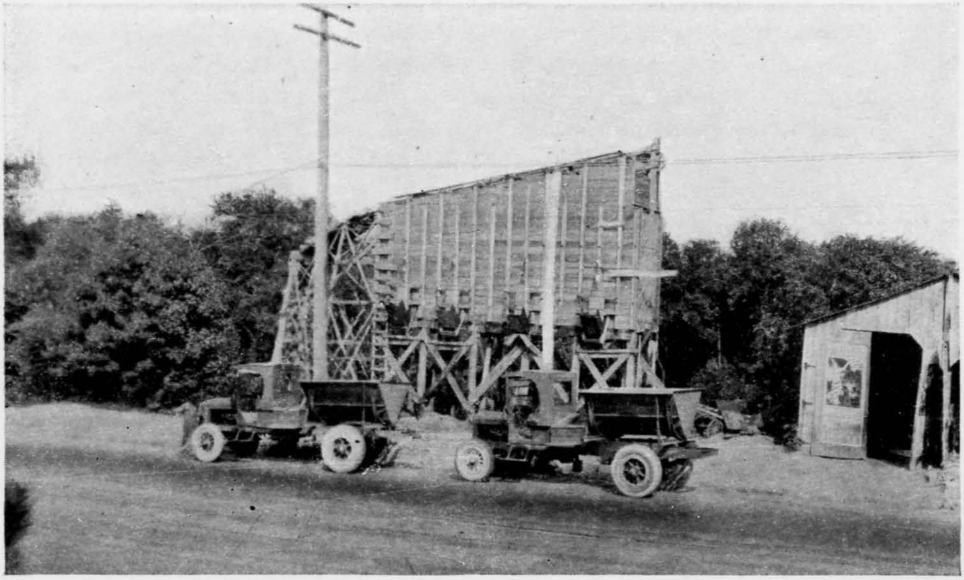
CHARACTER OF DEPOSITS

In placing a value on river or creek deposits of sand and gravel, the size of the stream, its rate of flow, and the amount of detritus carried must be considered, since it is on these factors that the replenishment of the deposits depend. Large streams like Ocmulgee or Oconee rivers will bring sufficient sand down during a rise of a foot or two to completely replace sand that has been removed during months of pumping.

The stream bed is an important matter also. Where it is shoaly and the water swift, there is little opportunity for very large deposits, but in the quiet reaches beyond the shoals, the slackened, sand-laden water deposits immense quantities of its burden.

Usually a prominent point on the inside of a curve is especially favorable for the collection of sand. The coarseness and quality of this sand will differ with the swiftness of the stream. Where the stream is broad and sluggish for long distances, a finer deposit is to be expected than in the narrow, swifter parts.

At the confluences of smaller, swifter streams with the main stream, the consequent slowing of the current of the smaller, sand-bearing streams usually produces thick sand or gravel deposits. Old millponds or areas of backed water due to damming further down the stream afford excellent settling basins for sand.



A. BINS AND DELIVERY TRUCKS, ACME SAND & SUPPLY COMPANY, PEACHTREE ROAD AT PEACHTREE CREEK, ATLANTA, FULTON COUNTY

B. LOOKING UP MAGRUDER CREEK FROM BRIDGE ON FORT GAINES-GEORGETOWN ROAD, 12 MILES NORTH OF FORT GAINES, CLAY COUNTY

TESTING

The sand supply which a stream, and particularly the smaller ones, is likely to maintain, is usually considerably over-estimated. An error of this character will be costly, since the installation of a pump and loading facilities requires a considerable money outlay. A depth of at least four feet of sand in the stream bed is necessary before pumping is warranted.

For local purposes small creeks 8 to 20 feet wide will usually produce sufficient sand. As the sand in such streams is usually underlain at a shallow depth of two or three feet by clay or mud, the actual thickness of the sand can be easily determined by forcing a strong stick or iron rod down into the sand. As long as it passes through sand it will require considerable energy to work it in, but the moment it enters the clay a marked contrast is noted, and the stick can be pushed in quite easily. A coating of blue clay may adhere to the lower part of the rod after removing it from the stream bed.

For finding the depth of sand and gravel in larger, deeper streams a man in a boat with a long iron or wooden pole can usually locate the sandy or gravelly areas by the gritty feel, as well as estimate their thickness by forcing the pole into the sand.

To obtain a sample of sand and gravel in deeper streams a tin pail securely fastened to the end of a strong pole is used. The sand should be taken at different points across the stream and also in the direction of flow. Samples representing as great a depth of the sand as possible should be obtained and all thoroughly mixed and quartered down to convenient size. Areas in the stream bed showing differences in the sand should be represented by separate samples.

In some larger streams the sand deposits are constantly shifting and it may be impossible to tell whether a great rise in the water stage will leave a large deposit, sweep the bed entirely clear, or change the character of the sand itself from place to place.

Estimation of the amount of sand carried daily by small streams is important. An approximation of this can be made by sinking a wooden box to the level of the top of the sand in the stream bed, and then measuring the amount of sand that collects in the box during a certain period. From this amount the total sand carried down by the entire width of the stream in a day can be easily figured which will serve as an estimation of what can be removed daily from the stream. Tests of this kind can also be made during a freshet to find the amount of sand likely to be replaced.

BANK DEPOSITS

Sand or gravel deposits outside a stream bed or bar may be broadly termed bank deposits. The most favorable places for detailed prospecting for bank deposits are along streams. In making such examinations it should be remembered that the stream was not always in its present position with respect to elevation, except in the case of those streams in the lowlands of the eastern Coastal Plain.

Throughout most of Georgia the streams have gradually cut out a valley for themselves of different depths depending on the age of the stream. In former ages the stream occupied different higher levels for some time, so that the deposition of sand and gravel was permitted. Hence careful search along the terraces of rivers or on the sides or top of hills near streams, but at present 15 to 100 feet above them, may prove successful. Deposits of this character occur along Little Ocmulgee River at and above Lumber City, along Coosa and Etowah rivers in Floyd and Bartow counties, along the first and second terraces of Chattahoochee River, south of Columbus, and along many other rivers and streams.

SAND-HILL DEPOSITS

Fluvial sand deposits.—Some of the most conspicuous sand deposits of the Coastal Plain of Georgia are those that occur along the left (east or north) banks of many of the larger streams. They are white, gray, and yellow; generally medium-grained, becoming a little coarser with depth; and, in many places, 20 to 40 feet in thickness. Their surface expression is undulating, sometimes hilly, with undrained depressions not uncommon. They support a scrubby growth of black-jack and pine. Deposits of this type are developed to a remarkable degree along Ohoopee River, west of Reidsville; Little Ocmulgee River, two miles northeast of Helena; Flint River, opposite Albany and Newton; and along Hurricane and Seventeenmile creeks, near Alma and Douglas, respectively. Their exact origin has been in doubt, although it is believed that wind has been an important factor in producing their present form.

When seen in sections (Fig. 9) the upper 5 to 10 feet show no signs of stratification, although this sand is usually finer than the rest of the deposit Below the upper part, practically all of those sand deposits examined, show a more or less distinct stratification consisting of thin, wavy, brown layers of clayey sand, making up about one-sixth of the total section, between thicker layers of clean, yellow sand. In some regions the clayey strata are so indefinite that a slightly darker layer, a few grains thick, is all that indicates them; elsewhere the clay may form so large a proportion of the bed as to spoil the sand for commercial purposes. The thickness of this stratified portion is from 10 to 20 feet, and it is usually succeeded below by a coarser, white, exceptionally clean sand, broken by lenses or strata of red clayey sand.

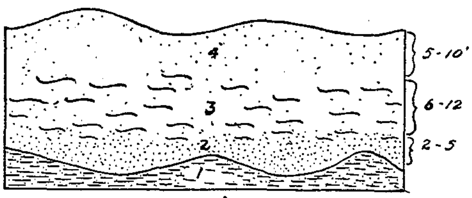


Fig. 9. Generalized section of Fall Line and fluvial sand-hill deposits.
1. Reddish-yellow clay.
2. White sand.
3. Yellowish to brown sand with wavy strata.
4. Gray to yellow, wind-blown sand.

From the distinctly stratified character of the lower part of practically all these deposits, together with their association with streams, it would seem that they were originally formed on both sides of the streams as flood deposits, the sand having been deposited when the current was swift, and when it became slower a thinner layer of clayey sand was laid down. Later, upon drying, this sand was easily transported by wind, and since the prevailing winds are from the south and west, it is natural to suppose that the sand on the south and west sides of the streams has been blown by the wind to the opposite sides where a greater thickness has accumulated. Much of the sand has, of course, been blown far beyond the stream banks, in fact, the origin of the widespread surficial interstream deposits, so typical of the Coastal Plain, and which cover a large part of South Georgia with sand to a depth of from a few inches to several feet, may possibly be explained in this way rather than to a recent advance of the sea. The fact that this surficial layer is simply a veneer on the older deposits and conforms closely to the present topography, together with the sharp contacts it makes with underlying red and yellow clays, or clayey sands, also indicates that its origin is neither marine, nor due to river terraces, nor is it always due to leaching of the iron oxide coloring material.

Similar deposits on the east and north sides of streams are known along Sautee River in South Carolina; along many streams in Western Florida and also along Red River in Texas.

Prospecting for medium-grained sand of this kind is a simple matter, consisting merely in visiting the east and north sides of the Coastal Plain rivers or larger creeks near railway crossings. Cannoochee, Ogeechee, Ohoopee, Altamaha, Satilla, and Little Ocmulgee rivers are particularly favorable for sand accumulation as well as a number of smaller creeks and rivers in the south and southeast part of Georgia.

Fall Line sand hills.—Heavy and extensive deposits of pale yellow sand occur along the Fall Line almost from Augusta to Columbus, either close to the Crystalline rocks or more usually separated from the actual Fall Line by from ½ mile to 5 miles. This sand closely resembles the fluvial sand hills of the Coastal Plain, but is more extensive and usually thicker. It is readily located by the scrubby vegetation of sharp-leafed black jack, and the general bareness of the area. In deposits so extensive as these the principal consideration is nearness to railway transportation.

FALL LINE GRAVEL DEPOSITS

The vicinity of the Fall Line along the entire eastern United States is favorable for sand and gravel deposits, since it represents the general outcrop of basal deposits of great rivers and of the sea upon an ancient shore. Deposits of this kind, particularly when close to their source, are apt to contain large percentages of gravel and sand. Much evidence of gravel can be found along the Fa'l Line in Georgia, at and near the tops of the uplands, or hills, especia'ly near the cities of Augusta, Macon, and Columbus.

In passing southeastward from the areas of schists and gneisses in the Coastal Plain the first deposits encountered are usually gravels with layers and lenses of clay. Examples of these are clearly seen along the Hamilton road four miles from Co'umbus and along the Mitchell and Mayfield roads a few miles south of Warrenton. Gravel indications are particularly abundant near the intersection of large streams with the Fall Line, as along Chattahoochee, Flint, Ocmulgee, Oconee, Ogeechee, and Savannah rivers. The deposits usually occur at or near the tops of terrace hills along the rivers, but in the interstream areas the gravels may occur underlying almost any type of topography. Their thickness, however, is usually much less than those near the rivers. This entire region has numerous water wells which, together with road-cut data, render a detailed search for gravel simple, and productive of definite results.

Gravel deposits in other parts of the Coastal Plain do not appear to follow any regular arrangement. Where indications of them are found, further search is invariably most profitable on the tops of hills, or on the hillsides near the top.

Considerable gravel occurs along Chattahoochee River on its upper terraces and especially along tributary streams from one to two miles back from the river. These deposits usually are found at or near the top of hills, but they may compose both the first and second bo - toms of the tributaries, and extend for some distance back from them.

TESTING

The money and time spent in a preliminary examination and testing of supposed sand and gravel deposits is spent simply to insure, in a measure, any future outlay that may be made in their development. Its necessity may be unapparent to some, but the wisdom of such work has been demonstrated on numerous occasions, when it has disclosed conditions which, if disregarded, would have resulted in considerable financial loss. Although considerably more extensive and less subject to injurious lateral variation than most mineral deposits, sand and gravel beds very frequently and commonly pinch out or deteriorate in quantity in short distances. It is to determine the character of the numerous layers both in thickness and quality, that detailed investigation of a reputed deposit is so desirable. Road and railway cuts, rain-worn gullies and exposures along streams, or even the surface expression and vegetation of the deposits will genera ly serve as an index of their character. Lacking these a careful examination of dug or bored wells in the area should be made, either by actual inspection of the well, or if this is impossible, by obtaining the data from the well digger or wel' driller.

In districts where the local peculiarities of the sand or gravel are already well known, evidence such as the foregoing might furnish, may be sufficient to base an opinion as to the value of the deposit; more usually, however, such data serves merely to reject a deposit entirely, or to warrant the time and expense of a more detailed examination. When a sand deposit is believed to fully warrant such work the best way to test it is by boring and digging holes either by hand, post-hole augers, or post-hole diggers. Pits are by far the best means of prospecting a sand deposit, since clay-free sand will not stand unsupported long enough to go sufficiently deep with augers or post-hole diggers. The holes should be laid off in some regular fashion either in regular or staggered rows equally separated. In the method shown by Fig. 10 the maximum distance any point in the tested area can be from a hole or pit is 35 feet; and in that shown in Fig. 11 the maximum distance is 40 feet. In the first method 25 holes would be necessary to completely test an acre, and in the second only 18 are needed. Pits should be dug so that an accurate representative sample can be obtained, and the actual thicknesses of gravel and clay or sand layers measured. Holes or pits need not be so closely spaced where the deposits tend to considerable regularity; usually the distance between pits can be changed to suit the local conditions.

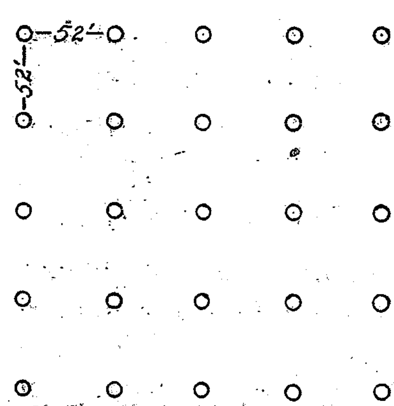


Fig. 10. Method of placing test pits on an acre of ground by quadrilateral system.

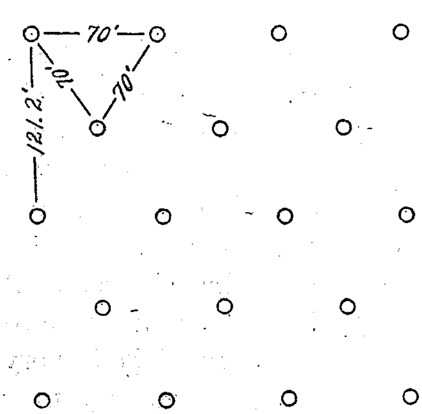


Fig. 11. Method of placing test pits on an area of slightly more than an acre by staggered system.

The data obtained from the test pits should be plotted on a map of the property upon which the relief has been indicated by rough contours, in order to show the relation between the overburden and the slope of the ground. This data should consist of a description of the nature of the material penetrated, with its thickness; the thickness of waste material, both above the commercial sand and gravel, or intercalated; the depth of the pit; the depth to water and the approximate amount of water and a description and samples of the sand and gravel. Where any considerable change is encountered from one pit to another, or at different levels in the same pit, a separate sample should be taken to be tested.

Sampling.—Probably the most difficult thing in connection with the examination of a sand or gravel deposit is the sampling. Minor changes in a bed occur so quickly that even if a sample is to represent the true character of the material within a radius of a few feet it must be very carefully selected. It must represent the entire face sampled and not a few feet of the best material. To accomplish this a narrow trench should first be scooped or picked out; the point of a shovel or the mouth of a sample bag is then held close to the face and moved slowly down as the uniform removal of the sampled material progresses, taking care that everything is caught. In this way there is greater possibility of obtaining an equal amount of material from each inch or foot of the face.

Where the sand or gravel is of the same general character throughout the pit, a number of samples taken as indicated from different parts of the pit should be assembled and thoroughly mixed and then smoothed out into a circular area. This circle should be divided into quarters; two diagonal quarters should be rejected, and the two remaining mixed and again quartered, the operation repeated until a sample of convenient size has been obtained. If the pit shows differences from one part to another, samples representative of each part should be treated in the manner just described.

In many Georgia sand deposits, even in those apparently most uniform, careful scrutiny will show two or more grades of sand, which if handled separately would be more profitable. In such deposits it would be unwise to judge the whole by a mixture of two or more parts, unless no attempt is to be made to grade the sand. On the other hand, a high rating placed on the pit on the basis of a very high-grade sand, occurring only over half the area, would manifestly lead to inconvenience, if not ruinous trouble. By properly blending (see pp. 48-49) two types of sand occurring in the same pit, a mixed sand may be obtained for which a higher price may be had than for either of the unmixed grades.

If the sample is to be shipped a folded paper should be put inside with the description written in pencil, as well as a description or number on the outside. Canvas or cotton bags holding from 10 to 25 pounds are suitable for most purposes, although for refined work air-tight tin containers are used for larger samples.

CONDITIONS AFFECTING DEVELOPMENT

Workable thickness and extent.—The thickness of a deposit necessary to warrant the expense of opening will depend on the scarcity of the material, its accessibility, and its quality. Due to distance from railroads, large deposits of sand 20 to 30 feet thick in Crawford and Taylor counties, and along many South Georgia streams are not being worked, but in regions where sand is much less plentiful deposits of from 4 to 6 feet are being profitably utilized. No definite limits can be placed on the thickness factor due to the influence of local conditions. As a rule, however, a deposit of less than 10 feet, without overburden, is hardly worth spending much money on, unless there is a large and steady demand for the product, with excellent transportation. If we assume that 20,000 tons, or 600 cars, of sand can be dug from an acre of sand 10 feet thick, one acre would last one year, shipping two cars a day. It is well to be sure of at least 20 years' supply before spending much money on machinery and trackage.

Since the thickness will largely determine the manner of recovering the sand or gravel, it is necessary that a reliable approximation of the thickness be found. The extent will also affect the installation of expensive, high-capacity machinery, and hat also should be carefully determ'ned.

In the case of glass sand Burchard[1] recommends at least 20 acres where the deposit is 20 feet thick. This material was in the form of sandstone and required a crushing and screening plant, costing from $10,000 to $50,000, for the preparation of the sand. It is safe to say that in South Georgia deposits of glass sand one quarter the above amount, say 10 feet thick and covering 10 acres, could be worked profitably with proper transportation facilities, since usually no plant is required.

Cover.—The thickness and character of the cover or overburden of a deposit is of extreme importance. Most sand and gravel deposits in Georgia have very little or no cover (one to two feet). Deposits with as much as 6 or 8 feet have been worked where the demand is great. Sometimes a loamy, sandy overburden is mined with the sand itself. A soft cover is of course easier to remove than one

1 Burchard, E. F., U. S. Geol. Survey Mineral Resources, 1911, pt. 2, p. 636, 1912.

partially indurated. In hydraulic removal, clay requires more water and a greater slope than loam or sand. Since the cover is likely to differ in thickness from one part of the pit to another, it is wise to determine its thickness and character beforehand by adequate holes or pits. In gravel deposits the cover usually increases as the top of the hill is approached, but in the Fall Line and fluvial sand deposits generally little difference is shown.

Rejected material.—In examining a pit, it is of great importance to note the amount of clay lenses, or poor sand, that must be discarded. Sand lenses, unless ferruginous, are undesirable in clay gravel for use in road construction. Clay lenses, and more than 10 or 15 per cent clay, even though well distributed in such gravel is also undesirable.

Certain lenses may show indications of organic matter. Sand deposits lying in, or only a few feet above the bed of a sluggish, swamp-bordered stream are likely to contain organic matter in amounts large enough to reduce the mortar strength by from 10 to 20 per cent. Another source of organic matter in bank deposits is the vegetation washed into the pit from the unbroken ground above, or the filtration of vegetable material from the surface into the sand to a depth of even 4 to 6 feet. The practice in many localities, of mining with the sand the surface vegetation consisting of leaves, grass, and small shrubs, rather than running a drag over the surface to clear it of this material, is certainly not to be recommended where a high-grade, and consequently higher priced, product is the aim.

Lime and alkali crusts as well as layers of limonite or iron oxide may occur, and they should be noted, as well as their amounts.

Variations.—Changes in the character of the sand or gravel itself or in the overburden should be watched for. In localities where the preparation of sand and gravel on a large scale is the leading industry, it is becoming increasingly evident that the concern that can furnish a uniform, dependable product, month in and month out, is the most successful. The maintenance of a uniform product is possible only by keeping careful watch on the deposit to note changes in it, and to alter the mode of treatment so that these changes will cause least increase in cost and possibly even decrease the cost; and, if the deposit and the market warrant, by installing washers and screens to insure constant uniformity.

Water.—Water may determine the depth to which a pit can be developed by a certain method, hence the importance of getting information regarding it. The depth at which water is encountered can generally be estimated from wells in the region. Very little trouble has been experienced in Georgia sand pits from water. Many of the sand deposits are located on hills or elevated areas where the water is considerably below, or from which it can easily be drained.

In sand and gravel pits, or near sand and gravel deposits, standing water may be due to a substratum of impervious clay a few inches, or feet, below, which should be considered in judging the depth of the deposit.

Where steam power, or hydraulic stripping or loading is used, a regular, adequate, and convenient water supply is necessary. With this in view a sand deposit, if possible should be opened from the side requiring least force to raise the water. A possible economy by recovering the sand with a centrifugal pump from an artificial lake created in the sand deposit should be considered, especially where plenty of water is at hand.

Accessibility.—Unless a sand and gravel deposit is within teaming or trucking distance of a good market (one to three miles) it is practically useless to attempt to open it unless situated directly on a railroad. The intrinsic value of sand and gravel is so low that freight rates are responsible for over half of its cost to the consumer. Deposits on lines running directly to markets are in far better position than those requiring one or more transfers to other railroads before the principal market is reached. In Georgia much sand territory, and some good gravel deposits are eliminated because of distance from markets or railroads.

Persistent deposits of sand in the beds of Oconee, Ocmulgee, Ohoopee, Altamaha and other South Georgia rivers, although inaccessible to rail transportation, are ideally located for large boat shipments. It is likely that these deposits will be more fully utilized in the future.

SANDSTONE DEPOSITS[1]

Extensive deposits of sandstone, quartzite, and quartz occur in the Paleozoic and Piedmont areas of Georgia. Practically none of these deposits are now being utilized, but they afford a possible future

---

1 For detailed quarrying methods see Bowles, Oliver, Sandstone quarrying in the United States: U. S. Bureau of Mines Bull. 124, 1917.

supply of sand for glass and refractory brick purposes. Such deposits are usually easily traced by their outcrop. Due to their resistance they generally form long, narrow ridges, such as the ridges of northwest Georgia; or Pine and Oak mountains, north of Columbus.

The bedding planes or strata of these deposits are generally apparent, although inclined at a considerable angle to the horizontal. This inclination is called the *dip.* The *strike* of such a deposit is the direction the strata take across country, or the direction at right angles to the direction of dip.

SAMPLING

Since the contents of the same bed in a deposit of this nature are more apt to be uniform than those of several different beds, samples are always taken at right angles to the strike, or across the dip, so that they include portions of each bed. Pieces of uniform size are taken at uniform intervals, or a narrow groove is cut across the cleaned rock surface, and the cuttings used as samples. These may be crushed and quartered if too bulky. Samples should be taken at intervals of from 25 to 100 feet along the dip, or closer, if the material shows marked changes. Where changes occur from bed to bed, each bed, or each group of beds showing similar characteristics, should be separately sampled.

In prospecting inclined or dipping beds of sandstone it must be remembered that the width of the outcrop in such cases does not represent the true thickness of the sandstone bed, but that the width of the outcrop increases proportionately as the dip of the rock increases, and may be two or three times the actual thickness of the bed. This factor also influences the thickness of the cover or overburden, since the more steeply a bed is inclined the greater the depth to the bed from a point at a given distance from the surface outcrop.

THE SAND AND GRAVEL INDUSTRY

The demand for sand and gravel in 1919 and 1920 has been very large in Georgia as elsewhere. The shortage of railway cars, together with an unfair distribution of the supply, has compelled a number of plants to cut down their production by half and even two-thirds, although the overhead expense of these plants is practically the same as when they maintained a maximum production, so that they are unable to make as fair a return on their investment as they are entitled to.

Whether the demand for sand and gravel is temporary and will cease after the housing shortage, occasioned by the war, has been overcome, is uncertain. Although the total cost of construction work in Georgia is exceeding that of any previous year, it must be remembered that the actual volume of construction is considerably below the record, since the cost in 1920 is over double that of 1912.

Owing to the abnormal conditions it would be well at this time to be cautious in installing too expensive sand-handling machinery, but in view of the fact that the volume of construction itself may not be considered remarkably abnormal when compared with some other years, a moderate expenditure for more efficient handling methods is advised.

Production and value of sand in Georgia from 1912 to 1919

Year	Building sand		Gravel		Molding sand		Engine		Other uses	
	Tonnage	Value	Tonnage	Value	Tonnage	Value	Tonnage	Value	Tonnage	Value
1912	304,882	$116,614	86,540	$37,554	------	------	10,245	$2,640	7,225	$2,325
1913	355,289	132,381	18,792	15,970	6,500	$4,919	2,700	650	17,700	8,500
1914	200,309	51,782	12,244	7,875	10,427	6,247	5,032	865	16,830	5,175
1915	527,258	163,932	22,848	15,071	3,898	2,883	1,865	390	------	------
1916	319,467	77,081	39,889	20,148	3,545	1,756	10,889	1,801	10,091	3,127
1917	257,880	78,409	27,149	32,975	31,793	8,950	33,342	6,568	6,600	1,950
1918	187,171	75,253	18,500	19,900	35,001	12,705	15,121	3,800	[1]6,862	6,864
1919[2]	269,059	131,511	13,106	13,766	64,491	33,883	9,091	4,988	30,614	20,345

[1] Glass sand.
[2] Figures are preliminary and subject to revision.

As the margin of profit on sand and gravel is so small, probably in no other business is there greater need for business acumen and foresight if ultimate success is desired. The failures of enterprises formed to produce sand and gravel have been numerous both in Georgia and in the United States at large. Many of these failures were due to the expending of more capital in plants and machinery than the demand and market price of the product warranted, so that the interest on the capital could not be met after all other necessary expenses had been paid. Failure in less pretentious enterprises has been due to ill-advised location of the pit with respect to quantity of sand and gravel, and to distance from, and size of the principal markets. Rarely can a sand plant be made to pay where it is necessary to ship the product over two or more independent railways. In some instances failure has been attributed to mismanagement and neglect to watch the many small leaks through which any possible profit may vanish. These include machinery, methods of production, and track layout unsuited to a particular deposit; failure to constantly utilize labor or machinery which is creating expense; variableness of product so that the consumer cannot depend upon its character from one shipment to the next; loss of sand in transit through chinks in freight cars, such loss may amount to from 15 to 20 per cent of the original shipment

Prices.—In the smaller towns throughout the state where the sand supply is obtained from local pits, no production or price record is kept, but it is likely that the amount of sand so obtained will equal one-third of that for which records are kept. Sand from such local sources may either be had for the expense of hauling, or on payment to the owner of the pit of a small amount ranging from 5 to 25 cents a yard, although larger sums have been demanded. At other places, where the demand is greater, the owner or leaser of the pit uses his own delivery trucks or teams and may charge from \$1.00 to \$1.50 a yard for the delivered sand. At larger pits where shipment is made by rail, brick and plaster sand costs from 40 to 60 cents a yard, although 50 cents was the usual price in 1920; coarser sand, for concrete, costs from 75 cents to \$1.00 a yard. Gravel at the pit costs from \$1.00 to \$3.00 a yard, depending on the demand.

Average price per yard of sand and gravel in Georgia and the United States

Year	Building sand		Glass sand		Molding sand		Gravel	
	Georgia	U. S.	Georgia	U. S.	Georgia	U. S.	Georgia	U. S.
1912	$0.38	$0.33	--------	$0.97	--------	$0.61	$0.43	$0.27
1913	0.37	0.32	--------	1.06	$0.76	0.63	0.84	0.24
1914	0.26	0.33	--------	0.97	0.60	0.64	0.66	0.23
1915	0.31	0.30	--------	0.85	0.70	0.59	0.65	0.26
1916	0.24	0.32	--------	0.97	0.51	0.69	0.50	0.31
1917	0.30	0.40	--------	1.38	0.29	0.92	1.22	0.48
1918	0.40	0.50	$1.00	1.94	0.37	1.04	1.08	0.57
1919	0.45	--------	1.01	--------	0.53	--------	1.05	--------

Royalties.—In many cases sand or gravel property is leased and the owner pays a fixed sum per yard or car produced, and may or may not be required to pay for a minimum production. For brick or mortar sand the royalty is $2.00 a car, and for gravel from 5 to 25 cents per yard, although in 1920 the average for gravel was 15 to 20 cents. In some places an annual rent is paid the owner of a sand deposit regardless of the amount produced.

To recover sand from navigable streams pe mission must be obtained from the United States War Department by a petition which describes the details of the proposed business. On other streams the owner must be consulted.

Labor costs.—In 1920 unskilled labor in sand pits cost usually about $3.00 per 10-hour day, although in some places such labor could be had for $2.50 to $2.75, elsewhere as much as $3.25 and $3.50 had to be paid. In many places the contract system is in use and the men paid a certain rate for each car loaded by hand, ranging from $4.00 to $6.00, depending on the amount of selection required and the difficulty of loading.

Markets.—The principal markets open to Georgia sand producers are Atlanta and Birmingham, provided the pits are on direct lines to these points. Macon and Savannah, although producing sand within their limits, use some sand that has been shipped in. Due to proximity to stone-crushing plants and to the cheapness of Birmingham slag, Atlanta, and to a large extent Macon, are independent of the gravel supply. Augusta, Columbus, and Rome, owing to the large amounts of sand and gravel locally available, use practically no imported product. In most of the other Georgia towns of 2,500 population and upward there is a brisk demand for both the finer grades of plaster and mortar sand and for coarse concrete sand and gravel. The following is a list of the sand and gravel producers of the State:

SAND AND GRAVEL PRODUCERS IN GEORGIA IN 1920

Acme Sand and Supply Company, Atlanta, Georgia.
Alexander Sand Company, Junction City, Georgia.
Allon Sand Company, Zenith, Georgia.
Altamaha Supply Company, Brunswick, Georgia.
Atlanta Sand and Supply Company, Atlanta, Georgia.
Atlantic Coast Line R. R. Company, Wilmington, N. C. Pit at Darrow, Ga.
Augusta Silica Mining Company, Augusta, Georgia.
Baum, Leo P., Dublin, Georgia.
Brockman, Edward, Ringgold, Georgia; molding sand.
Brown, O. O., Sand Company, Howard, Georgia.
Central of Georgia Sand Company, Howard Georgia; steel molding and building sand.
Clark, J. H., Ringgold, Georgia; molding sand.
Crutchfield, F. A., Flintstone, Georgia; molding sand.
Dillon, J. W., Thomasville, Georgia.
Downing, J. J., Nicholls, Georgia.
Downs, L. J., Junction City, Georgia.
Gailey, C. K., Conyers, Georgia; molding sand.
General Building Supply Company, Savannah, Georgia.
Georgia Sand and Gravel Company, Augusta, Georgia.
Harkey, W. C., Sand Company, Mauk, Georgia.
Heath, John M., Talbottom, Georgia.
Hime Sand Company, Junction City, Georgia.
Hinson Sand Mines, Lumber City, Georgia; glass and building sand.
Houser, J., Tivola, Georgia.
Kirkpatrick Sand and Cement Company, Birmingham, Ala.; steel molding and building sand.
Lumber City Sand and Concrete Company, Lumber City, Georgia.
McElroy, J. E., Norcross, Georgia.
Macon Fuel and Supply Company, Macon, Georgia.
Morningstar, L. E., Junction City, Georgia.
Morris, W. Mercer, Columbus, Georgia.
Puckett, C. A., Emerson, Georgia.
Rome Sand and Gravel Company, Rome Georgia.
Rutledge & Chestnut, Columbus, Georgia.
Smiley Sand Company, Atlanta, Georgia.
Thompson, J. T., Carrolton, Georgia.
Watson, N. G., Rome, Georgia.
Wiggins, T. O., Waycross, Georgia.

PHYSIOGRAPHIC AND GEOLOGIC FEATURES OF GEORGIA

PHYSIOGRAPHY

The physiographic features of Georgia present great contrast. From a flat, featureless plain near the coast, the relief gradually becomes more pronounced toward the northwest until steep, rugged mountains, almost 5,000 feet in height, are encountered in the extreme northern part of the state.

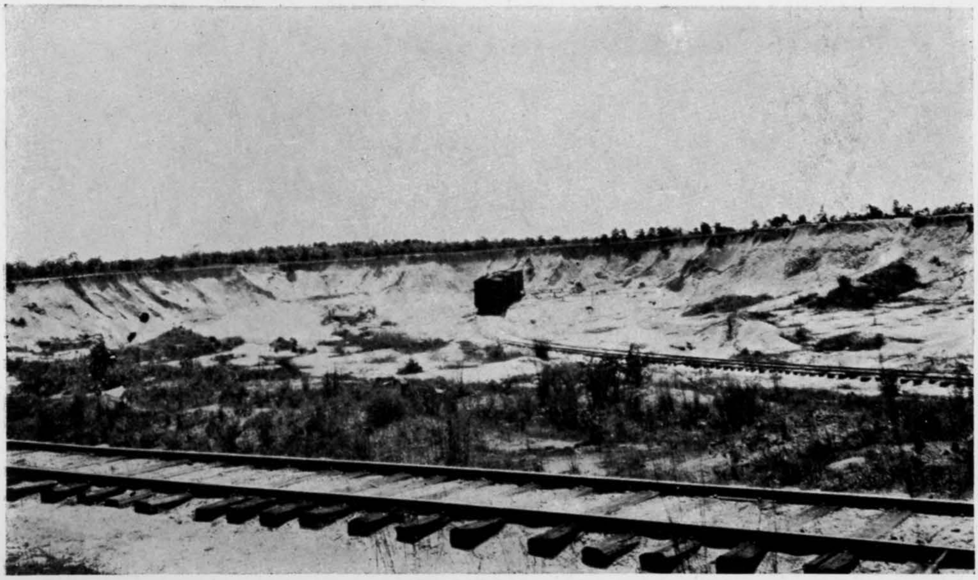
This diversity of topography includes five major divisions which occur in roughly parallel bands along the eastern border of the United States from New York to Alabama. These divisions beginning at the the Atlantic Ocean, are the Coastal Plain, which extends to the Fall Line, or roughly to a line passing through Augusta, Macon, and Columbus; the Piedmont Plateau, which extends from the Fall Line to the high mountain region of Georgia and is roughly limited on the north by a line from Clarksville through Marietta to Rockmart in Polk County; the Appalachian Mountains which extend from the Piedmont Plateau to the northern boundary of the state and on the east to the Appalachian Valley area, roughly marked by a line running south from Tennessee through Cartersville and Cedartown to Alabama; the Appalachian Valley, which extends west from the Appalachian Mountains and includes the rest of northwest Georgia except a small area in Dade and Walker counties; the Cumberland Plateau, which includes parts of Dade, Walker, and Chatooga counties in the extreme northwest corner of the state.

The physiographic divisions of the state will be described in more detail in the report preceeding the sections devoted to the description of the sand deposits of the geologic provinces of the state.

GEOLOGY

Owing to characteristic differences in origin, texture, and structure, the rocks of Georgia are separated into three distinct divisions which are common to the entire eastern border of the United States, where they occupy long, irregular, but roughly parallel belts. These three provinces are the Coastal Plain, the Paleozoic area and the Crystalline area.

The Coastal Plain strata occupy most of the region known as the Coastal Plain, which is a relatively flat plain paralleling a great part



A. GENERAL VIEW, C. C. McCARTY SAND PIT, 2½ MILES SOUTH OF GAILLARD, CRAWFORD COUNTY

B. MINING SAND BY LOCOMOTIVE CRANE AND CLAM-SHELL BUCKET, ALLON SAND COMPANY, 2 MILES SOUTH OF GAILLARD, CRAWFORD COUNTY of the entire Atlantic Coast of the United States. In Georgia it extends westward from the sea to the vicinity of the Fall Line which passes through Macon, Augusta, and Columbus. The Coastal Plain sediments consist of alternating beds of sand, clay, marl, and limestone.

The Crystalline area comes next, extending from the Fall Line from Alabama to Maine and forms the basement upon which the Coastal Plain sediments were deposited. It occupies all that part of Georgia northwestward from the Fall Line except all or part of eight counties in the extreme northwest corner.

The Paleozoic area occupies the seven or eight counties and parts of counties in the extreme northwest corner of Georgia not included in the Crystalline area. Limestone, shales, slates, and sandstones, which have been somewhat altered along the eastern margin, comprise this area.

Inasmuch as the sand and gravel deposits of Georgia are found throughout the entire state in all of its three geologic provinces possessing characteristics distinctive of the division in which they occur, the deposits of each will be treated separately.

DISTRIBUTION OF SAND AND GRAVEL IN GEORGIA BY GEOLOGIC PROVINCES

THE COASTAL PLAIN[1]

EXTENT AND SIZE

The Coastal Plain of Georgia includes, roughly, that part of the state from the Atlantic Ocean to the Fall Line. The Fall Line extends northeast and southwest across the state from Augusta through Milledgeville and Macon to Columbus and marks the location of rapids and falls in the streams as they pass from the hard crystalline rocks on the northwest to the soft or unconsolidated materials on the southeast. The area of the Coastal Plain is approximately 35,000 square miles, or seven-twelfths of the entire area of Georgia. It is part of the great Coastal Plain bordering the eastern United States which merges into the Gulf Coastal Plain bordering the southeastern states.

PHYSIOGRAPHY

In general appearance, the flat, or gently rolling topography of the Coastal Plain shows a marked contrast to the rugged, hilly, and even mountainous terrain peculiar to that part of Georgia north of the Fall Line. Much of the plain is practically the same as it was left when the sea retreated eastward. Its more rolling and even rugged appearance as one goes northwestward is due to its greater elevation and to the fact that the time elapsed since the retreat of the sea has been longer, and consequently more opportunity has been afforded weathering agencies and streams to cut into the original even surface.

Physiographically, the Coastal Plain is divided into a number of distinctive parts, which, beginning at the coast, are: the Satilla Lowland, the Okefenokee Plain, the Altamaha Upland, the Fall Line Hills, the Dougherty Plain, and the Southern Lime-Sink region.

---

1 Abstracted from the following sources:
Veatch, Otto, Geology of the Coastal Plain of Georgia: Ga. Geol. Survey, Bull. 26, pp. 25-50, 1911.
Stephenson, L. W. and Veatch, Otto, Underground Waters of the Coastal Plain of Georgia: U. S. Geol. Survey Water-Supply Paper 341, pp. 28-115, 1915.
Cooke, C. W. and Shearer, H. K., Deposits of Claiborne and Jackson age in Georgia, U. S. Geol. Survey Prof. Paper 120-C, 1918.

Satilla Lowland and Okefenokee Plain.—Commencing at the coast, a flat, sandy plain, from 40 to 60 miles wide, occurs broken only by gentle depressions produced by the larger streams. This plain, which includes the Satilla Lowland and the Okefenokee Plain, rises gradually from sea level to a height of 125 feet. The area is marked by swamps, including the famous Okefenokee[1] and Buffalo swamps, as well as less extensive swampy areas confined to the streams and coastal flats.

Altamaha Upland.—The Coastal lowland on the northwest merges into the Altamaha Upland. The approximate division runs from Springfield, in Effingham County, to Statenville, in Echols County. It is marked by gently rolling, park-like topography, ranging from 125 feet in elevation, near its eastern boundary, to 470 feet, where it merges into the Fall Line Hills. Streams are more numerous than in the Coastal Lowlands, and "wire-grass" and long-leafed pine are the outstanding types of vegetation. Most of the streams are bordered on their east or north banks by hilly belts of yellow sand, rising from a few feet to 50 feet above the streams themselves. The Altamaha region is considered by many to be the most beautiful in Georgia.

Fall Line Hills.—The relief of the Altamaha Upland becomes sharper until the Fall Line Hills are reached. The division runs roughly through Waynesboro, Tennille, Dublin, Cochran, Vienna, and thence along Flint River to Decatur County. It occupies a strip 40 to 50 miles wide extending across the state and merging into the Piedmont Plateau on the north. Its greater altitude and longer exposure to denuding agencies have produced a somewhat rugged, gullied terrain, marked by deep washes. The relief varies from 100 to 350 feet. The "red" hills are most prominent, but an extensive belt of gray sand hills, ranging from 4 to 7 miles wide, extends with some interruptions from Augusta almost to Columbus.

The remarkable gullies near Milledgeville, and in Stewart County, seven miles west of Lumpkin, are worthy of note in that they represent the extreme manifestation of modern erosion in this area.

The Dougherty Plain.—The Dougherty Plain, which occupies a wedge-shaped area between Flint and Chattahoochee rivers, extends

---

1 Veatch, Otto, Geology of the Coastal Plain of Georgia: Georgia Geol. Survey, Bull. 26, pp. 44-46, 1911.

north between the Fall Line Hills and the Altamaha Upland. It is a relatively level area, with few hills and creeks, but has numerous circular depressions or lime-sinks. It merges into the Fall Line Hills to the northwest, but rather sharply contrasts with the Altamaha Upland to the east.

The Southern Lime-sink region.—The Southern Lime-sink region occupies a narrow strip, 15 to 20 miles wide, along the southern border of the state, extending from the vicinity of Flint River to Allapaha River. The topography is rolling, the depressions being due largely to solution and caving of the underlying limestones.

GEOLOGY

As the Coastal Plain topography is so different from that of the rest of Georgia, its geology is even more unique when compared with that of the state north of the Fall Line.

Layer after layer of sediments ranging in composition from sand to marl, and in hardness from that of mud to flint have been deposited by terrestrial and marine agencies from the Lower Cretaceous Period to the present. These deposits, dipping gently to the southeast, form the youngest in the state and were deposited directly upon the upturned and truncated beds of the oldest rocks (Pre-Cambrian) in the state. Their thickness ranges from a few inches, near the Fall Line, where the ancient basement is exposed, to almost 4,000 feet along the eastern margin of the state. This variation is accounted for by the gradual recession of the sea, which exposed more and more of the area to erosion, while still depositing material at the eastern edge. For convenience and identification the deposits have been divided and subdivided into series and formations.

CRETACEOUS SYSTEM

LOWER CRETACEOUS SERIES

The Lower Cretaceous deposits extend in a very irregular belt from 2 to 30 miles in width from Augusta to Columbus and lie directly upon the Pre-Cambrian crystalline rocks. They consist chiefly of coarse, cross-bedded, arkosic, and clayey sands of fresh, shallow water origin, and lenses of clay approaching kaolinite in composition. Beds of pure white argillaceous sand and irregular, thin, deposits of clayey gravel occur through the formation. The sand if washed would be suitable for glass or construction purposes and the gravels are thick enough in many places to supply local road material.

UPPER CRETACEOUS SERIES

Eutaw formation.—The Eutaw formation is of relatively small extent in Georgia. Although its basal beds resemble those of the Lower Cretaceous, it overlies the latter unconformably. It consists of coarse, arkosic, micaceous sands interbedded with lenses of dark clay. The upper parts consist of compact, green, marine clays and lignitic beds, overlain by gray, limy, and clayey sand, and merging into sandy limestones in places.

Ripley formation.—The Ripley formation is exposed in central and west-central Georgia and is conformable with the Eutaw when the latter is present. The materials composing the Ripley formation are almost entirely marine, consisting of gray, limy fine-grained sands and clays.

The *Cusseta* sand member consists of irregularly bedded sands with smaller clay lenses. As a rule the sands are coarse-grained and resemble those of the Midway beneath.

The *Providence* sand member consists mainly of coarse- and fine-grained, irregularly bedded sands with lenses of clay.

TERTIARY SYSTEM

EOCENE SERIES

Midway formation.—The Midway is a shallow water, marine formation, consisting of colored sands and clays in the lower part, and of marls, clays, and thin, usually impure, fossiliferous limestones in the upper part.

Wilcox formation.—The Wilcox formation usually consists of sandy, glauconitic shell marl; dark lignitic sand; and lignitic sandy clay. In Schley and Macon counties red sands with pure white clay occur and are probably referable to the Wilcox.

CLAIBORNE GROUP

McBean formation.—The McBean formation is made up of sandy, shell marls and clayey, calcareous sands. Its extent is limited to valleys in Richmond and Burke counties. No sand or gravel deposits of commercial value occur in it. In southwest Georgia along Chattahoochee River blue- to ash-colored calcareous and sandy fossiliferous marls occur which belong to the Claiborne Group, and have not yet been differentiated.

JACKSON GROUP

Deposits of Jackson age attain in Georgia their greatest thickness east of Mississippi.

Ocala limestone.—The Ocala limestone is a thick deposit of flinty limestone and marl. Its largest extent is in southwest Georgia between Flint and Chattahoochee rivers, where it is usually marked by residual boulders of flint, and by soft, gray limestones that are encountered in wells.

Barnwell formation.—The Barnwell formation consists principally of argillaceous sand becoming red or mottled on weathering. Local clay and chert layers with occasional limestone beds occur. The lower part of the formation consists of clay lenses, most of which resembles fuller's earth. This material constitutes the Twiggs clay member. Although the Barnwell formation is exceptionally sandy, the sand is of such impure character that it is of little value for construction purposes.

OLIGOCENE SERIES

Chattahoochee formation.—The Chattahoochee formation outcrops in a strip a few miles wide from the vicinity of Cordele southwestward through Camilla and Bainbridge to the extreme southwest corner of the state. It consists of gray, compact, fossiliferous limestone, and a few thin sandstone layers and cherty replacements at its base. No commercial sand occurs in it.

Alum Bluff formation.—The Alum Bluff formation is of considerable extent in Georgia paralleling most of the streams of the Altamaha Upland and Southern Lime-sink region, and presents a number of varying lithologic phases. It is composed mainly of greenish, or gray, calcareous clays and marls interbedded with argillaceous and feldspathic sand and sandstones. Beds of coarse conglomerate and hard vitreous quartzite are fairly common. Beds of fuller's earth, rounded siliceous and calcareous nodules, and beds of low-grade phosphate are also characteristic of the formation.

Although considerable sand occurs in the Alum Bluff, it is usually so argillaceous as to be practically useless commercially. The conglomerate has broken up in places and thin, surficial deposits of clean gravel, well suited for concrete, have resulted.

PLIOCENE SERIES

Charlton formation.—The Charlton formation outcrops along the St. Marys' River, in Charlton and Camden counties. It is made up of soft, white, clayey limestone and fossiliferous clay and is not a source of sand or gravel.

QUARTENARY SYSTEM

PLEISTOCENE SERIES

COLUMBIA GROUP

Okefenokee formation.—The Okefenokee formation and the Satilla formation occupy a strip along the entire coast of Georgia approximately 20 miles in width. The Okefenokee formation occurs as a thin coastal terrace deposit of incoherent gray sand, and as terrace deposits bordering many of the larger streams of the Coastal Plain of Georgia.

The fluviatile deposits consist chiefly of red, clayey sands, pebbly in places, and coarse gravels. Along some of the streams a gray incoherent sand appears to be the only deposit. The gravels and sands occurring near Montezuma, Lumber City, Fort Gaines, Omaha, and Columbus are probably referable to this formation as are the gravels found along the Fall Line.

Satilla formation.—The Satilla formation occupies a terrace belt paralleling the Atlantic Ocean and extending westward from 20 to 30 miles. It consists of greenish and bluish marine clays, green sands, and thin gravel layers. The clays are generally massive, and the sands are fine-grained and white on the surface, but become gray to brown at depth. These sands are used locally for building purposes and as a source of brown dye.

The fluviatile terrace deposits of this formation form low plains a few feet above the Coastal Plain rivers and consist of clays, sands and gravels and afford sources of commercial gravel and sand in a few cases.

Undifferentiated deposits.—Extensive areas in the Coastal Plain are underlain by vari-colored deposits of sand, grit, and clayey sand which may be quite indurated in places. This material has generally been considered the equivalent of the Lafayette formation, but its exact age is uncertain, and in Georgia it is known as the Altamaha formation.

Its clay content is too large to afford a suitable source for sand, but its weathered products, accumulating in and along streams, afford numerous sources of sand for local use.

Surficial gray sands.—A great part of the Coastal Plain of Georgia is covered with a veneer of white to gray, fine-grained sands, ranging from a few inches to many feet in depth, their general average is from one to two feet. They attain a maximum thickness on the north and east sides (left hand) of many of the rivers and large creeks of the area, affording an almost inexhaustible supply of fine- and medium-grained sand. These sands are sometimes very pure, both in the stream bank deposits and in the widespread surficial deposits, making them suitable for use in the manufacture of glass.

Thick deposits of yellowish sand, ranging from 2 to 5 miles in width, parallel the Fall Line, with several interruptions, from Augusta almost to Columbus. A rough stratification prevails in the lower half of their thickness where the clay content usually increases. In places these sands are over 40 feet thick, although they usually range from 10 to 25 feet. Their exact age is uncertain, but it is probably comparatively recent. Numerous sand pits have been opened in these deposits along the railroads crossing them.

DETAILED DESCRIPTION OF INDIVIDUAL COUNTIES

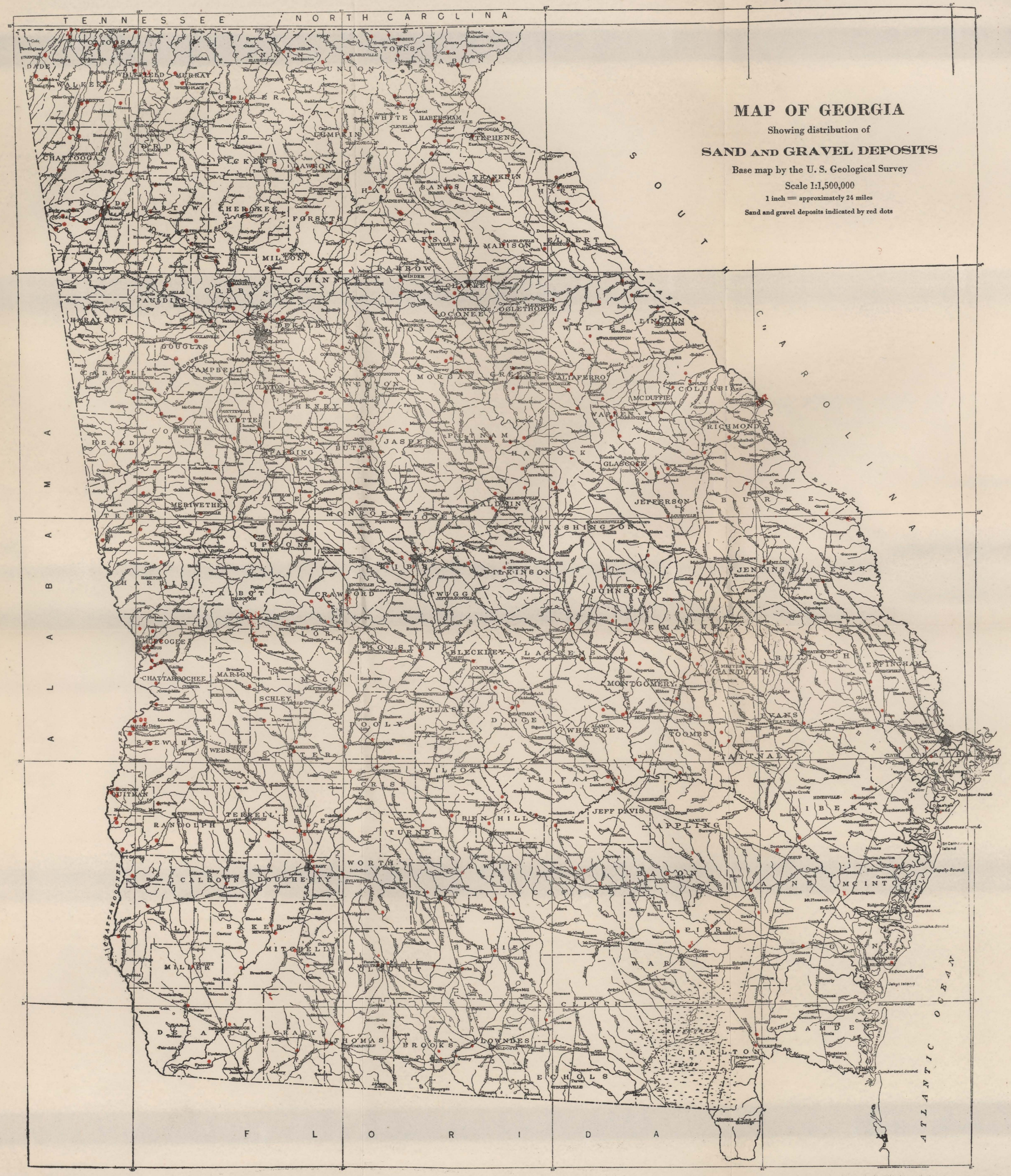
APPLING COUNTY

The surface of Appling County consists principally of gray sands underlain by sandy clays at depths ranging from one to eight feet. Sand is most abundant on narrow terraces along Altamaha River, which bounds the county on the north, and in small hills which irregularly line the north side of Little Satilla River.

The surficial sand is fine-grained and dirty, but some local deposits appear to be pure enough for glass. The best building sand occurs in the bed of Altamaha River and to a much less degree in Little Satilla River. Sand for local use is obtained from stream branches or from the surficial deposits.

ATKINSON COUNTY

Loose sand, ranging in depth from a few inches to 6 feet, and underlain by yellow and reddish clays, covers most of the county. No sand is commercially worked, although large deposits of pale yel-


MAP OF GEORGIA
Showing distribution of
SAND AND GRAVEL DEPOSITS
Base map by the U. S. Geological Survey
Scale 1:1,500,000
1 inch = approximately 24 miles
Sand and gravel deposits indicated by red dots
TENNESSEE
NORTH CAROLINA
SOUTH CAROLINA
ALABAMA
FLORIDA
ATLANTIC OCEAN

low, clean, medium-grained sand compose the upper half of hills from 30 to 45 feet high which extend in an almost uninterrupted belt along the east side of Seventeenmile Creek, and which are found to a lesser extent along Satilla River. Sand, suitable for brick mortar, plaster, or sand-lime brick, comprises from 1,000 to 2,500 feet of the width of the belts.

Some sand occurs east of Allapaha and Withlacoochee rivers, bounding the county on the west, but there is very little sand at the Georgia & Florida Railway crossing of Allapaha River. Bars of fairly coarse white sand occur along both rivers, but such sands are practically inaccessible due to the swamp.

Practically no sand of commercial value exists near a railroad, although the Atlantic Coast Line at Millwood approaches to within two miles of the deposits along Satilla River.

BACON COUNTY

Loose yellowish to white, fine- to medium-grained sand covers a considerable part of Bacon county to a depth of from 2 to 6 feet. Sometimes local deposits are sufficiently pure for the manufacture of glass, but distance from transportation prohibits their use.

Extensive sand hills border the east side of Big Hurricane Creek from the vicinity of Alma southward to the county line. This sand is yellow, medium-grained, and clean. It is particularly prominent along the Atlanta, Birmingham & Atlantic Railway, east of Alma, where it forms a belt 1,500 feet wide and over 10 feet thick. Seven hundred feet of this width exceeds 20 feet in thickness. Its greatest apparent thickness is 25 feet at a point 200 feet east of where the following section was taken:

Section of sand deposit on Big Hurricane Creek, east of Alma

	Feet
Sandy soil	1
Fine, yellow sand	4
Medium-grained yellow and gray sand	4–7
Irregular, poorly stratified sand. Reddish clayey sand forms strata lines ¼ to ½ inch wide occurring every 2 to 6 inches	4–7

The sand here is somewhat coarser and of better quality than the usual type of sand bordering the South Georgia streams. Sample *T-243*, representative of the deposit, has a fineness modulus of 1.40

and 41 per cent is retained on the 48-mesh screen. The organic matter shows a color value of 100. The sand is pale yellow and is composed almost entirely of sub-angular to angular stained quartz.

On the public road just east of Big Hurricane Creek bridge, and about one mile east of Alma, the local sand supply for Alma is obtained from a small pit. Sand also occurs in small quantities along Little Hurricane Creek in the western part of the county.

BAKER COUNTY

Thin, surficial sands, generally white, cover most of the area of Baker County. Bordering Flint River and Ichawaynochaway and Chickasawhatchee creeks, irregular terrace deposits of rather inferior sand occur. Good coarse sand occurs generally in Flint River, and medium-grained sand is found in small bars along the two creeks mentioned above.

A large sand bank occurs below the mouth of Ichawaynochaway Creek on Flint River at the Kelly place, and dunes of medium-grained, yellowish sand occur along Flint River 19 miles below Newton. This sand is quite similar to that occurring in Mitchell County opposite Newton. (See sample *T-220*, in table.)

The local sand supply of Newton is obtained from the banks of Cooleewahee Creek, half a mile north of the town on the Albany road. This sand is fine-grained, but is suitable for plaster or brick mortar. The whiteness of this sand suggested its use for glass-making and an analysis was made.

Analysis of sand from Cooleewahee Creek, Newton

Magnesia (MgO)	0.12
Alumina (Al_2O_3)	0.12
Iron oxide (Fe_2O_3)	1.27
Silica (SiO_2)	98.21
Total	99.72

BALDWIN COUNTY

No sand or gravel is commercially worked in Baldwin County, although sand in large quantities occurs in Oconee River, and small gravel deposits are scattered over the county near the Fall Line.

Baldwin County pit.—Six miles southwest of Milledgeville on the Upper Macon road (Dixie Highway) a small pit has been opened in a deposit of coarse, red, clayey sand, with gravel layers from 6 to 18 inches thick, in the upper and lower parts of the pit and underlain by mottled clay. The deposit extends along the road for 400 feet and for a little over half that distance to either side of the road, covering about 4 or 5 acres. The red, gravelly sand and clay is about 7 or 8 feet thick at the center of the pit and is used for local road material. Sandy, gravelly clay of this character is rather common in the county, particularly in the southern part.

Red, coarse, clayey sand 6 feet thick occurs in cuts along the road from the Lower Macon road to Darling, a quarter of a mile from the Macon road. On the Lower Macon road between 4 and 5 miles from Milledgeville, cuts expose a maximum of 10 feet of red, coarse sand with a few pebbles and some white kaolin balls scattered through it.

Similar sand 7 feet thick occurs in the village of Darling on the Milledgeville-Gordon road close to the railroad. Such sand is of little value except for local road purposes, unless freed of its clay content.

Oconee River.—Oconee River has immense quantities of excellent medium- to coarse-grained sand in its bed which can be easily obtained at Milledgeville by pumping. This sand was used in the construction of the electric plant at Milledgeville and the concrete is of remarkably high quality.

Fishing Creek.—Fishing Creek, which runs close to the Georgia Railroad from near Milledgeville to the Jones County line, has deposits of clean, coarse sand suitable for concrete work along most of its course. A small amount occurs in this creek near the crossing of the Dixie Highway, a mile southwest of Milledgeville. Eight miles west of Milledgeville, where the Georgia Railroad crosses it, 10 feet of medium- to coarse-grained, clean, concrete sand occurs along the creek banks for some distance along the stream. This deposit may be large enough to warrant development.

Camp Creek.—On the Gordon road, 4 miles from Milledgeville, brown sand similar to that found in Oconee River, occurs in Camp Creek from 5 to 10 feet thick and over an area 75 feet wide along the stream. The banks above are composed of red, pebbly, clayey sand for 200 feet back from the stream.

BEN HILL COUNTY

In many parts of Ben Hill County a fine-grained, gray sand occurs, from 2 to 4 feet thick, but it is of no value commercially.

Fitzgerald.—Very little good sand occurs close to Fitzgerald, although a fine-grained sand is found covering the surface to a shallow depth just north and northeast of the town near the Camp Brooklyn road. Most of the local sand supply is obtained from the Sydney Clare pit, 3 miles northwest of Fitzgerald on the Seba (Rochelle) road.

Sydney Clare property.—Fairly good coarse sand occurs on the Clare farm just to the south of the Seba road. The following section is exposed:

Section of Sydney Clare property, 3 miles northwest of Fitzgerald

	Feet
Soil and coarse, gray sand	1
Coarse, yellowish sand, somewhat clayey but well graded	2
Pale red, coarse sand, wavy stratification lines ¼ inch thick and ⅕ to 1 inch apart. Parts are indurated for 3 or 4 inches showing large clay content	3–4
White to yellowish, medium- and coarse-grained sand with small amount of clay	1–2

Irregular layers, 2 to 3 inches thick, of pebbles from ½ to ¾ inches in diameter occur through the sand. Sand has been removed from about two acres, but apparently several times that area still remains untouched, the thickness of which ranges from 4 to 8 feet. In places the thickness is decreased by the underlying clay coming almost to the surface. On the whole, the sand should make good concrete. It is hauled to Fitzgerald in trucks and teams and used locally. Sample *T-235*, representative of this sand, has a fineness modulus of 2.71, and 88 per cent is retained on the 48-mesh sieve. It has just a trace of organic matter. The sand is pinkish-gray and the coarser quartz grains are rounded, but those less than 10 mesh are angular.

This sand, occurring as it does at a comparatively high elevation, is a remnant of an ancient stream deposit, probably Pleistocene in age. Similar high-level deposits of sand in smaller quantities and less favorably situated commercially, occur at a few other points in the county, notably north of Ashton School on the Broxton road, and at Union School in the extreme eastern part of the county.

Allapaha River.—Along the eastern side of Allapaha River, in the western part of the county, is a belt of sand ranging from 400 to 800 feet wide and from 8 to 15 feet thick. The sand is of medium coarseness, clean, and white to pale yellow. It is mined for local use south of the Fitzgerald-Rebecca road, just east of Rebecca. It forms low bluffs 15 to 20 feet above the river bed and 300 feet back from it and has a width of 400 feet. The sand averages about 10 feet in thickness, the upper 6 feet is loamy, but the lower 4 feet, as exposed in the pit, is composed of coarser, clean, white sand.

This sand belt continues along the river in both directions beyond the county boundaries, but its occurrence at the Atlanta, Birmingham & Atlantic Railway crossing 2¼ miles southeast of Rebecca is worthy of note. The belt at the railroad is about 700 feet wide, beginning 800 feet east of the trestle, and is 15 feet thick over most of the width; 10 feet of this, however, is below the railroad grade. No stratification lines occur in the sand, nor does it appear to have ever been mined. It is similar in character to the sand along Seventeen-mile Creek near Douglas (see *T-234* in table). Another extensive area of shallower sand of this type occurs in the northern part of the county on both sides of House Creek.

Numerous bars of excellent coarse-grained sand occur in Ocmulgee River, which bounds the county on the northeast, but this is practically inaccessible except for transportation by boat.

BERRIEN COUNTY

Loose, gray sand covers a large part of Berrien County to depths ranging from 1 to 10 feet. Clays and sands alternate to a depth of about 50 feet below the surface near which level Alum Bluff strata are encountered.

Nashville.—The local sand supply for Nashville is obtained 1.2 miles northwest of the town on the Tifton road, 200 feet west of Withlacoochee River. This sand is said to be the best close to Nashville and is rather fine-grained but suitable for plaster and brick work. The lower white sand is a little coarser and cleaner and is the best.

Section at small sand pit, northwest of Nashville

	Feet
Loamy, yellow, fine-grained sand	4–5
Yellowish-white to white fine-grained sand	3

Sample *T-237*, representative of this deposit, has a fineness modulus of 1.42 and 44 per cent is retained on the 48-mesh sieve. The organic matter in the sand shows a color value of 500. The grains are mostly of stained, angular quartz.

The sand along Withlacoochee River is not so prominent as along Allapaha River or other rivers, and at the crossing of the Georgia & Florida Railway there is practically none of any account. At Sandy Bluff, however, west of the river, and a third mile south of the railroad trestle, north of the Adel road, the sand is 10 feet thick, usually yellowish to white, and fine-grained in texture. This sand is not available, as a cemetery covers most of the area.

Allapaha River.—The sandy belt east of Allapaha River continues through Berrien County, but is much thinner and narrower, and the sand is of poorer quality than in Irwin County to the north. At the Ocilla Southern Railroad crossing, near the Allapaha-Ocilla road, 4½ miles north of Allapaha, only from 3 to 4 feet of silty, fine-grained sand is exposed in the cuts, although it probably attains a greater thickness. The belt is half a mile wide here, but clay comes close to the surface at several points. A somewhat coarser sand occurs south of the river in a small deposit 4 or 5 feet thick.

At the Atlantic Coast Line Railroad crossing of the river, 3 miles east of Allapaha, a poor grade of sand, very fine-grained and silty, shows in the railroad cut 500 feet east of the trestle. The belt is 2,000 feet wide, but 1,000 feet of this exposes yellowish red clay beneath, and in the rest of the cut the thickness is from 8 to 10 feet, although in places it is thinner. To the north of the railroad the hill rises somewhat indicating a thickening of the sand. In the river itself a small bar, typical of the bars occurring at intervals along the river, and made up of white, coarse sand, occurs.

The entire northern part of the county is very sandy. Dug wells have passed through from 5 to 10 feet of coarse, gray sand in many places, and in some instances a thickness of 15 feet and more has been noted. Two miles east of Milltown the Satilla terrace is prominent and is about 15 feet above the river. Veatch[1] gives the following section:

Section at wagon bridge two miles east of Milltown

	Feet
Pleistocene	
Satilla formation	
3. Brownish or chocolate-colored sand, gray or white over the surface of the plain	5
2. Brown or yellow, coarse sand, quartz, and quartzite pebbles, also contains small white pebbles of phosphate	2
Oligocene	
Alum Bluff formation	
1. Greenish, laminated sandy clay	8

Glass sand.—At many places thicknesses of from 3 to 5 feet of pure white sand occur associated with cypress swamps and other undrained depressions. The original yellow or gray sand has probably been leached of its iron oxide content by the organic acids produced in the swamp humus, and the sand is apparently pure enough for glass manufacture. Deposits of this kind occur throughout the county; their thickness is uncertain and they depend upon the size of the swampy area for their extent. The sand is of little value now, due to lack of rail transportation, but it may be a future source of supply.

Pure, white sand also underlies the yellowish sand to a thickness of from 3 to 6 feet along Withlacoochee River and represents ancient deposits made by the river. No analyses were made of any of this sand, but the reader is referred to the analysis of *T-238* (p. 180), a similar sand occurring west of Little River on the Adel-Moultrie road.

BIBB COUNTY

Sand is produced commercially in Bibb County from Ocmulgee River, at Macon, and was formerly mined at Hardy's Crossing. Numerous gravel deposits occur near the city of Macon, and some of these are used as a local source of road and building material.

Ocmulgee River.—The Macon Sand and Supply Company operates two 6-inch Morris centrifugal pumps driven by 25- and 35-horsepower engines from the west bank of Ocmulgee River about 1,000 feet above the Spring Street bridge in the city of Macon, on the Southern Railway. The river at this point is normally from 2 to 5 feet deep, and the nearest shoals are one mile above, consequently the spot is

1 Veatch, Otto, and Stephenson, L. W., Geology of the coastal plain of Georgia: Georgia Geol. Survey, Bull. 26, p. 445, 1911.

well located to maintain a constant sand supply. Each pump is capable of producing from 7 to 8 carloads a day, using up to 250 feet of pipe, and pumping can be carried on as deep as 20 feet, or until solid rock is reached. With every additional 20-foot joint of pipe after 250 feet, the sand capable of being pumped daily is reduced one-half carload. The sand from the river is run through a half-inch mesh screen, which is laid across the car as it is loaded, to rid it of twigs and other foreign matter, and it then passes into the car from which the water and clay drain off leaving the clean sand behind. It is necessary to stop with wood all cracks and chinks in the car larger than a quarter inch or a large proportion of the sand will be lost in transit. This work may take as much time as the actual loading of the car. No trouble has been experienced since the pumps were installed in obtaining an adequate supply of sand. Sample *T-7 A*, representative of the sand as shipped, shows a fineness modulus of 2.83 and 95 per cent retained on the 48-mesh sieve. A concrete strength ratio test made by Prof. F. C. Snow at the Georgia Tech Laboratory gave 128 and 131 per cent of normal at 7 and 28 days, respectively. It contains only a trace of organic matter. The sand is used locally or shipped to Atlanta and other points on the Southern Railway in Georgia.

East of the river, opposite Macon, generally a few hundred feet from the stream, patches of coarse, gray sand, well suited for concrete work, are found. These deposits are usually small, rarely more than an acre in extent and from 1 to 6 feet deep, but they should afford a local supply of fairly good sand.

Further back from the river the sand becomes finer and on the slopes of the second terrace it is dug from banks along the roads or streets and hauled across the river to Macon. Sample *T-63*, obtained a few hundred feet north of the Central of Georgia Railway, about a third mile from the river, shows a fineness modulus of 1.75 and 37 per cent coarser than 48 mesh. Practically no organic matter occurs in the sand. Such sand is suitable only for brick mortar and should only be used for concrete where a coarser sand is not available.

Walnut Creek.—Three miles northwest of Macon, where the Camp Wheeler road crosses Walnut Creek, near the county line, the creek is 25 feet wide and has a bottom 250 feet across. Fairly good

A. WATER PIPE AND SAND SLUICE USED IN HYDRAULICING SYSTEM, ATLANTA SAND & SUPPLY COMPANY, 1 MILE SOUTH OF GAILLARD, CRAWFORD COUNTY

B. GENERAL VIEW, ALTAMAHA SUPPLY COMPANY, 3½ MILES EAST OF EVERETT CITY, McINTOSH COUNTY sand in large quantities occurs in the bed and along the banks of this stream and should be well suited for local construction and road-building work.

Hardy's Crossing.—For two or three miles southeast of Lizella on the Macon & Birmingham Railway, a very sandy belt, an extension of the one so prominent in Taylor and Crawford counties to the south, occurs. One mile west of Hardy's Crossing there is an abandoned sand pit of an acre in extent, to which a spur track has been laid. The cut shows from 10 to 12 feet of sand which is underlain by yellow clay. The sand is gray, fine-grained, and below the upper foot or two it is very clean and free from organic matter.

Tittle property.—Mrs. J. M. Tittle of Macon, owns 13 acres at Hardy's Crossing. Prior to 1908 sand was shipped from this property. The pit, just east of the crossing, covers over an acre. About 10 acres of this property appear to be underlain by sand from 6 to 15 feet deep. The sand is gray and coarser than that west of the crossing. Sample *T-10*, obtained from the pit face on this property, shows a fineness modulus of 1.93 and 69 per cent coarser than the 48-mesh sieve. The sand contains only a trace of organic matter. It is grayish-yellow and except for a few grains of feldspar and ilmenite the sand is composed of clean, angular quartz grains. This sand is well suited for brick and plaster mortar and may also be used for concrete, although a coarser sand would be preferable.

One mile east of Hardy's Crossing, ten acres appear to be covered with sand to a depth suitable for commercial development. The sand is similar to that further west.

Sand in small amounts, but of good quality and sufficient for local road uses, occurs along and in Rocky, Tobesofkee, and Echeconhee creeks, throughout most of their courses in the county.

GRAVEL DEPOSITS

Macon.—The Fall Line, or contact of the unconsolidated Cretaceous sediments and the ancient Crystalline basement, runs across Bibb County from northeast to southwest, passing through the city of Macon. The clays and sands just southeast of this contact are favorable places for the occurrence of gravel. A number of such deposits exist in the county, but they are usually too thin or of too limited extent to warrant extensive commercial development. They afford a fair supply of road material and have also been used, after removal of the clay by washing, for concrete aggregate. In the vicinity of Macon the gravel occupies the hill tops south and west of the city.

Just west of the Central of Georgia Railway yards, 2 miles south of Macon, and a little north of the overhead bridge, clay gravel from 5 to 10 feet thick occurs, generally at or near the tops of hills. The pebbles are of sub-angular quartz and range from ¼ to 4 inches in diameter, although their average size is from 1 to 2 inches. In the road paralleling the railroad, and about 1,000 feet west of it, two road cuts show the following section:

Section 1,000 feet east of Central of Georgia Railway two miles south of Macon

	Feet
Pebbly, sandy soil	3
Clay gravel	2–5
Red, clayey sand	1–2
Sandy, clay gravel	1–5

The lower bed in the section is very irregular, changing to white sand and thinning out entirely in short distances. It also contains limonite concretions. The gravel exposed in this section does not extend to the top of the hills to the east which are underlain by another layer. Probably a total of 30 acres are underlain with gravel in this locality. Sample *T-60,* taken from the upper layer in the section given above, shows a fineness modulus of 6.46 and 76 per cent retained on the 4-mesh sieve, with 18 per cent of the pebbles larger than 1¼ inches. The clay content of 12 per cent makes an excellent cementing material, adapting the gravel for use in road construction. If washed of the clay it would make concrete aggregate. The pebbles are rounded, granular quartz, but are rather soft and easily broken.

A cut on the Central of Georgia Railway 5 miles south of Macon was also examined.

Section on Central of Georgia Railway, 5 miles south of Macon

	Feet	Inches
Sandy soil	2	
Red, clayey, well-cemented gravel	2	
Reddish-brown clay	5	
Red clayey gravel	3	6
Red, clayey, slightly indurated sand	12	

This material is suitable only for road purposes, as the proportion of gravel is too small to warrant washing. It is typical of the Cretaceous gravels in the vicinity of Macon. The sand at the base has variable lenses of white kaolinitic sand from 1 to 3 feet thick containing black specks of ilmenite. Sample *T-8*, representative of the white, kaolinitic sand so common along the Fall Line, shows a fineness modulus of 2.59 and 92 per cent coarser than the 48-mesh sieve. The clay content is 15 per cent. Such sand would make excellent concrete aggregate if washed of its clay and if found with a cover thin enough to warrant mining.

A cut on the Central of Georgia Railway 4½ miles south of Macon shows the following section:

Section 4½ miles south of Macon on Central of Georgia Railway

	Feet	Inches
Sandy loamy soil	1	
Medium grained, yellow, clayey sand	1	
Red, clayey quartz gravel	1	6
Coarse grained, clayey sand	1	6
Clayey, quartz gravel	2	
White, kaolinitic sand containing pebbles of white kaolin	15	

The upper sand in this section contains too much clay for use in building, but when mined with the gravel should make a good, well-cementing road material. The white sand at the base of the section was analyzed to determine its value for glass purposes, but the iron content of 1.25 per cent is too high. This iron occurs mostly combined with titanium in the mineral ilmenite, which occurs through the otherwise pure white sand in small, almost invisible, black specks.

Analysis of white sand on Central of Georgia Railway, five miles south of Macon

Moisture at 100°C	0.06
Loss on ignition	1.93
Lime (CaO)	trace
Magnesia (MgO)	0.34
Alumina (Al_2O_3)	3.95
Ferric oxide (Fe_2O_3)	1.25
Titanium dioxide (TiO_2)	0.36
Silica (SiO_2)	92.56
Total	100.45

Six miles south of Macon on the Central of Georgia Railway, cut show lenses of gravel 1 to 2 feet thick. These lenses may unite to form a deposit of good road gravel 5 or 6 feet thick. About 5 acres appear to be underlain with clay gravel a quarter mile north of Rutland Station. The overburden is variable and may be too thick to permit recovery of the gravel. The irregularity and thinness of the gravel must also be considered.

Macon-Columbus road (Wire road).—Many outcrops of gravel occur along the old "Wire" road between Macon and Lizella. North of this road, 3¼ miles from Macon, small pits have been opened in the gravel. It is a sand gravel only a foot or two thick and most of it has been removed. The cut on the south side of the road shows 5 feet of clay gravel.

A mile south of the road at this point a high hill, clearly visible from the road, is capped with a sandy, clayey quartz gravel. A pit was in operation on the south side of the hill about 1914, and most of the gravel was hauled away for construction purposes after having been first washed and screened at the pit. The opposite side of the hill appears to still contain considerable gravel, although not so good as that on the south side. A pile of good coarse concrete sand containing about 25 car loads has been formed from the gravel screenings. The hill contains about 15 acres either in the pit or untouched, and the gravel ranges from 1 to 4 feet in thickness.

On the Columbus road, 7 miles from Macon, clay gravel up to 8 feet in thickness appears in road cuts for 500 feet. The upper 4 feet of the gravel is usually sandy, but the lower part has a red clay matrix. A well on the Amerson property, at the 7-mile post, is 17 feet deep, and shows only a few feet of gravel at the bottom. Further west of this road 4 or 5 feet of clay gravel is exposed in a road cut west of a small ditch. Sample *T-66* is typical of the clay gravel along the Columbus road and was obtained at the cut on the Amerson property. It shows a fineness modulus of 6.44 and 73 per cent coarser than 4 mesh. The clay content is 14.3 per cent, it has a high cementing value, and is composed of tough, quartz pebbles. A large deposit may exist up or down the branch from the Columbus road.

Saunders' property.—From 15 to 20 acres on the Reuben Saunders' property, 1½ miles west of Lizella, are covered with coarse, quartz gravel. Most of this has worked down from the tops and sides of surrounding hills where it is at the most about 5 feet thick and covers from 1 to 2 acres.

Castleberry property.—The Robert Castleberry property, two miles west of Lizella on the Knoxville road, and a quarter mile from the Macon & Birmingham Railway, has a sandy gravel deposit covering several acres. Prospect pits dug in 1917 are reported to have penetrated an average of 2½ feet of gravel. The pebbles are of fairly tough granular quartz and range from ½ to 3 inches in diameter. the gravel is used locally and although this deposit is probably the largest in this vicinity it would not warrant commercial development except to supply the local demand for concrete or road building.

BLECKLEY COUNTY

The Ocala limestone underlies the northern three-quarters of Bleckley County, and the remainder is covered with the variegated clays and sands of the Altamaha formation. Sand for even local construction purposes is of rare occurrence throughout most of the county, and none is produced for commercial purposes.

Some sand occurs east of Gum Swamp Creek, but the amount is small and the quality poor. Sand used for construction purposes in Cochran is generally scraped up from ditches or obtained from nearby branches. A sample from a small branch north of Cochran is typical of the sand found in such small deposits. This sand (*T-245*) is yellowish-brown, and the grains are mostly angular quartz. The fineness modulus is 2.13 and 75 per cent is retained on the 48-mesh sieve. The organic content shows a color value of 100.

BROOKS COUNTY

The surface of Brooks County is mostly sandy and underlain at depths of from a few inches to several feet by clays and clayey sand and still deeper by Alum Bluff strata which outcrop along some of the streams. Although considerable surficial sand exists in the county, deposits of commercial value are meager.

Quitman.—Sand for use in Quitman has been obtained from a pit on the A. S. Perry property, 1.4 miles east of Quitman on the Valdosta road, just west of Okapilco Creek. About one and a half acres have been uncovered showing a maximum thickness of from 4 to 5 feet of loamy, fine-grained sand becoming coarser near the bottom. At the east end of the pit the sand is somewhat coarser and of better quality. From 1 to 2 feet of sandy soil must be removed to expose the building sand. Sample *T-240*, taken from this pit, shows a fineness modulus of 1.49 and about 45 per cent is retained on the 48-mesh sieve, indicating a rather fine-grained sand. The organic content shows a color value of 100.

Similar deposits, less favorably situated with respect to roads, occur a half mile south of Quitman on the South Georgia Railway, and one mile east of the town on the Atlantic Coast Line Railroad. A small deposit also occurs 1½ miles north of Quitman on a plantation road leading north from the lumber mill.

Okapilco Creek.—A fairly coarse, clean, gray sand obtained from Okapilco Creek, 2 miles north of the Quitman-Valdosta road, has been used in the construction of the concrete bridge across that creek. The sand is much better than any seen elsewhere around Quitman.

Withlacoochee River.—Withlacoochee River, forming the boundary between Brooks and Lowndes counties, has a number of bars of coarse, white sand; similar, although somewhat finer sand, is found along the stream above the channel, particularly near the Blue Springs bridge. The sand is underlain usually with blue or green clay at a depth of from 2 to 5 feet.

The Satilla terrace which extends along Withlacoochee River about 20 feet above the bed is covered with fine-grained sand which becomes coarse and even pebbly a few feet below the surface. No samples of this sand were analyzed, but some of it appears sufficiently pure for glass manufacture.

Other deposits.—Small scattered deposits of sand, ranging from loamy and clayey to coarse and clean, occur throughout the county, especially on terraces, or on the terrace slopes of streams. Deposits of this character occur on both sides of Piscola Creek as far west as Dixie. A rather large deposit is found just west of Piscola, in the southwest part of the county, and near Ochlawilla Church in the southeast part of the county. Most of these deposits are so far from railroads as to be of only local value.

BRYAN COUNTY

No commercial sand pits are operated in Bryan County. The potential sand and gravel deposits of value are restricted to bars in and along Canoochee and Ogeechee rivers and to sand belts north and east of Canoochee River.

Canoochee River.—Sand hills occur east of Canoochee River, but their height is not so great as along Altamaha River at Barrington and Ludowici. On the Claxton-Pembroke road, east of the river from 5 to 7 feet of yellow, fine-grained sand has been deposited upon clay. In the river bed, and in bars, there are large quantities of white, medium- to coarse-grained sand from a few hundred square feet to almost an acre in extent suitable for building purposes. This sand in the river bed has the property of whistling or singing when the heels are shuffled through it. The Seaboard Air Line Railway crosses the river west of Groveland and furnishes the only means of transportation of sand for commercial purposes from the river in the county, except in the eastern part of the county where the main line of the Seaboard crosses the river north of Ways Station.

Ellabell.—Along the Ellabell-Clyde road, 3 miles north of Clyde, a coarse sand grading into a fine, sandy gravel occurs for a distance of 1,000 feet. The gravel appears to be confined to the tops of the higher areas, and although it may appear extensive on the surface, it is not likely to exceed 2 feet in thickness at any point. No railroad runs within 5 miles of the material.

On the Ellabell-Guyton road, 3 miles north of Ellabell, a cut shows 6 feet of fine-grained, loamy sand and red clay beneath. Deposits of this character are typical of the county and are of questionable value even if located on a railroad or close to a market.

Other deposits.—Throughout the county the surficial sand ranges from 2 to 8 feet in depth and is underlain by yellow, red, and blue plastic clays. This sand is fine-grained and has a large amount of organic matter and is of poor quality for building purposes; occasionally, however, it becomes coarser and cleaner and suitable for such uses.

The white sand exposed in the bars of Canoochee River is believed to be sufficiently pure for the manufacture of glass. Constant replenishment of the bars would go on if they were to be exploited, but the most serious question at present is that of transportation.

BULLOCH COUNTY

No sand is produced in Bulloch County in quantities large enough for shipment.

Statesboro.—Most of the sand used locally in Statesboro is obtained from the J. B. Lee pit, on the Savannah road about a mile from the courthouse. The pit covers 1½ acres, and the sand as shown ranges from 10 feet in thickness at the northwest end to 6 feet at the southeast end.

Section at southeast end of J. B. Lee's pit, Statesboro.

	Feet
Sandy soil	1
Fine-grained, yellow sand	3
Medium-grained, yellow sand	2
White, medium-grained sand of irregular extent and thickness	1–2
Reddish-yellow clay	1+

The northwest end of the pit shows a reddish-brown clayey sand of inferior quality. The sand is hauled to all parts of Statesboro, the price depending on the length of the haul. A slightly higher charge is made for the white sand. The sand was used in concrete paving of the streets of Statesboro. Sample *T-264*, from this pit, showed a fineness modulus of 2.12 and 80 per cent coarser than 48 mesh.

Ogeechee River.—Ogeechee River has in its bed, along practically its entire course on the northeast and eastern margin of the county, coarse sand and gravel from 1 to 3 feet thick and very little mud or clay. At the crossing of the Savannah road (Dixie-Overland Highway) the sand and gravel is particularly prominent and was used in the concrete work on the new bridge constructed in 1920.

The east and north sides of many of the streams in the county have deposits of fine-grained sand. This is especially true of Lotts Creek. East of Register and near the Central of Georgia Railway, the belt is 500 feet wide and from 4 to 10 feet thick.

BURKE COUNTY

Considerable sand occurs in Burke County near Keysville and in and along Savannah River, and gravel is reported on the southeast edge of the county, but neither sand nor gravel is produced commercially in the county at this time.

Waynesboro.—Sand for local use in Waynesboro is obtained from the Glenn Fulcher property, on the Augusta road, two miles from Waynesboro. The part dug over is about two acres, ranging from 2 to 4 feet deep, and the sand is fine-grained, loamy, and white, suitable only for brick mortar. Sample *T-263*, from this pit, has a fineness modulus of 1.68 and 54 per cent coarser than 48 mesh.

Keysville.—In 1895 considerable sand was shipped from the J. P. Clarke property in Keysville to an Augusta glass company, and in 1906 an elaborate plant for the manufactu e of cement blocks was installed and operated for a few years. The sandy area in and around Keysville covers about 500 acres. The upper 2 to 4 feet is usually a clean, white sand, sufficiently pure for glass making.

Analysis of white sand from J. P. Clarke property, Keysville, T-262

Loss on ignition	0.30
Lime (CaO)	0.00
Magnesia (MgO)	0.14
Alumina (Al_2O_3)	0.55
Ferric oxide (Fe_2O_3)	0.32
Manganous oxide (MnO)	0.09
Titanium dioxide (TiO_2)	0.14
Silica (SiO_2)	98.30
Total	99.84

Beneath the white sand is from 5 to 15 feet of yellow, fine- to medium-grained sand below which red and white clay, interbedded with coarser yellow sand, occurs. Sample *T-262*, from this deposit, has a fineness modulus of 1.75 and 68 per cent coarser than 48 mesh. As two lines of the Georgia & Florida Railway diverge at Keysville, there is adequate rail transportation.

CALHOUN COUNTY

The surface of Calhoun County is usually covered to a depth of from a few inches to several feet with gray, fine-grained sand. No commercial sand deposits are either worked or known in the county. Sand for building purposes is usually shipped in from Albany or Columbus or else scraped up from creek beds or ditches.

Fine-grained sand occurs in the beds or along the banks of Chickasawhatchee, Ichawaynochaway and Pachitla creeks, but the amount is small and the quality poor. Small areas of white sand are scattered through the county near streams or sloughs, and an analysis of some from Pachitla Creek on the Morgan-Arlington road is given.

Analysis of sand from Pachitla Creek, Morgan-Arlington road, Calhoun County

Iron oxide (Fe_2O_3)	2.00
Silica (SiO_2)	97.10
Total	99.10

The iron content of this sand is too high for glass-making.

CAMDEN COUNTY

The surface of Camden County is covered with sand which is underlain by clays and clayey sands. Sand is obtained commercially from St. Mary's River above St. Mary's. Deposits of black sand occur on the coastal islands which may be later utilized as a source of the rarer elements and are described in Appendix B, p. 377.

St. Marys.—According to S. W. McCallie,[1] sand from the bed of St. Mary's River is loaded on barges and shipped to St. Mary's and the adjoining coastal islands for local use. Most of this sand is obtained 2 or 3 miles above the town and is a fairly coarse, clean, white sand.

CANDLER COUNTY

No sand or gravel has been produced in Candler County except for local purposes.

Metter.—The best sand close to Metter occurs on the W. L. Jones place, 3 miles south of the town on the Cobbtown road. The overburden is 2 feet thick, but the sand is coarse-grained, clean, and hence of excellent quality. The deposit covers several acres.

1 Oral communication.

Deposits of fine-grained sand are common throughout the county, but they are not suitable for concrete work. A deposit of this kind occurs on the J. M. Lee property, 2 miles northwest of Metter.

Fifteenmile Creek.—Fine-grained sand, from 8 to 15 feet thick, occurs in a belt from 500 to 1,000 feet wide east of Fifteenmile Creek along most of its course in the county. At the Central of Georgia Railway crossing east of Metter, the belt is 800 feet wide and the sand 10 feet deep. Further north the sand becomes deeper, and the belt widens until about 5 miles north of the railroad where it appears to reach its greatest development.

Canoochee River.—A belt of fine- to medium-grained, gray to yellow sand about a mile wide extends east of Canoochee River along its entire course in the county. The sand ranges from 10 to 35 feet in depth, and its topography is rolling. The sand is exposed along the Central of Georgia Railway east of Canoe Station, although only a part of its total thickness can be seen. The deepest cut is 500 feet west of the station and shows 8 to 10 feet of sand for 900 feet. A well at the sawmill, north of the railroad, and 10 feet below the top of the highest part of the sand hill at this point, encountered over 15 feet of yellow sand. West of the first railroad cut is a depression which is succeeded by 1,500 feet of what appears to be deep sand, although only a small cut was necessary here for the railroad. Sample *T-265*, from this deposit, has a fineness modulus of 1.71 and 65 per cent coarser than 48 mesh.

CHARLTON COUNTY

The eastern part of Charlton County is flat and sand-covered, while the western part forms a portion of the great Okefenokee Swamp. Incoherent white and yellow sands cover a large part of the county. They are underlain by red and white sands and clays of Pleistocene or Pliocene age, and still deeper by the clays, marls, and limestones of the Charlton formation.

Folkston.—Gray to white sand becoming pale yellow at a depth of a few feet is exposed just east of Folkston, according to Veatch.[1] The sand here averages 6 to 8 feet in thickness, but locally it attains a depth of 15 to 20 feet. Elsewhere in the county the sand ranges in depth from 2 to 15 feet. Along St. Mary's and Sa-

1 Op. cit., pp. 426, 427.

tilla rivers, the sand has been piled up into a permanent ridge which borders these rivers particularly on the west.

St. Mary's River.—A number of sections observed by Veatch[1] along St. Mary's River show from 2 to 6 feet of white to brown sand belonging to the Satilla formation and occuring from 10 to 25 feet above the river bed. It is likely that sand of this type attains a thickness of from 15 to 20 feet throughout the county, but very little of commercial value lies close to the railroads.

A deposit of brown to black indurated sand cemented with organic acids from which brown dyes are made, lies three miles west of St. George, and smaller deposits of lower grade material have been found along the Suwannee Canal near Camp Cornelia. A detailed description of these deposits is given on page 373.

CHATHAM COUNTY

The surface formation of most of Chatham County consists of fine-grained quartz sands of the Satilla formation. Argillaceous sands with reddish and bluish clays occur beneath the surficial sands and in places are exposed at the surface. Sand is commercially produced from Savannah River. Bank deposits of sand are scattered through the county, particularly along Ogeechee River.

Savannah River.—The General Building Supply Company of Savannah, of which Mr. F. H. Opper is presid nt, has been dredging from the bed of Savannah River from 5 to 6 miles above Savannah since 1911. A one-yard clam-shell bucket is operated by means of a 40-horsepower hoisting engine on a dredge boat, and the sand is piled on a lighter of 100 cubic yards capacity and towed to a wharf at the city, from which it is transferred to boats for shipment to Jacksonville, Charleston, and sea-coast points, or to railroad cars for interior shipment. The sand in the river bed ranges from 1 to 8 feet deep and generally lies in long, narrow strips parallel to the direction of the stream. The river is from 16 to 18 feet deep. The coarser sand is found in the deeper part of the channel and the dredge generally works there. Beneath the sand a white gravel is usually found, the pebbles being about one inch in diameter. The gravel or sand is underlain by gray mud or clay. In order for the dredge to work effectively there should be at least 4 feet of sand in the river bed. The dredge has been working in practically the same location, 6 miles

1 Op. cit., pp. 393, 400.

west of Savannah, opposite the Whitehall plantation, since 1916. A hole may be dredged out during the day, but it is usually filled up over night. Sample *T-35*, taken from the lighter during dredging, shows a fineness mudulus of 2.19 and 93 per cent coarser than 48 mesh. The color value of the organic content is 100. Concrete tests of sand from Savannah River made by the Pittsburg Testing Laboratory, gave a tensile strength of 229 pounds per square inch or 100 per cent of the strength of concrete made from standard Ottawa sand. Tests of sand from bed No. 4, and reported to Mr. W. F. Brown, county engineer, showed 109 per cent of the standard sand strength.

Analysis of sand from bed of Savannah River, 6 miles north of Savannah

Soda (Na_2O)	0.10
Potash (K_2O)	0.15
Lime (CaO)	0.24
Magnesia (MgO)	trace
Alumina (Al_2O_3)	1.94
Ferric oxide (Fe_2O_3)	1.15
Manganous oxide (MnO)	trace
Titanium dioxide (TiO_2)	1.33
Silica (SiO_2)	94.85
Total	99.74

Salt Creek.—Excellent, quartz gravel is reported to occur beneath the marshes adjoining Salt Creek, near the Seaboard Air Line Railway crossing. The material is spotty, however, and is found in two layers separated by a layer of mud, 2 or 3 feet thick. The upper layer is 3 feet thick and the thickness of the lower layer has not been determined. The spotty character and the thinness of the deposit has prevented its development up to this time.

A narrow belt of fine-grained, yellow sand lies north of Ogeechee River westward from the old Ogeechee Canal. The deposit is nowhere more than a mile wide, and its thickness ranges from a few feet to 12 feet. It is typical of the fluvial sand hills common in South Georgia and is of small value at this time.

On a small branch entering Ogeechee River from the north, and crossed by the Savannah-Darien road, 12 miles south of Savannah, a white sand is found which is representative of much of the sand occurring along the streams in Chatham and adjoining counties.

Analysis of sand from Ogeechee River branch, 12 miles south of Savannah, T-34

Loss on ignition	0.20
Alumina (Al_2O_3)	0.01
Ferric oxide (Fe_2O_3)	0.79
Titanium dioxide (TiO_2)	trace
Silica (SiO_2)	99.06
Total	100.06

The iron content of the sand is low enough to warrant its use in the manufacture of colored bottle glass, if a deposit sufficiently large for commercial development can be located along a railroad.

CHATTAHOOCHEE COUNTY

Although no sand or gravel is commercially exploited in Chattahoochee County, large deposits of sand are found not far from the Central of Georgia and Seaboard Air Line railways in the center of the county, and also in Upatoi Creek. Gravel is found on the terraces overlooking Chattahoochee River.

The Fall Line sand-hill belt crosses most of the northern part of the county where it is from 2 to 4 miles wide, and the sand ranges in depth from 5 to 15 feet. The extent of the belt is not so uninterrupted as is true in Taylor, Talbot, and Crawford counties, nor is rail transportation so convenient. Between Ochillee and Christopher the Central of Georgia Railway follows Ochillee Creek and no sand is exposed except in the stream bed, although considerable quantities of sand occur on the higher ground from a quar er to a half mile from the railroad, between these two points.

Upatoi Creek.—Excellent deposits of coarse, white sand and gravel occur in bars along Upatoi Creek almost from Chattahoochee River to the Buena Vista road. Large bars are especially prominent at and between the Seaboard Air Line and Central of Georgia railway bridges. The terrace above the creek contains some gravel that has been used for local road building.

Fort Benning Military Reservation.—Although no longer part of the county, deposits of gravel formerly included in the county and now in the reservation may be mentioned here.

Just within the main entrance to Fort Benning 8 miles from Columbus a small pit has been opened with a ½-yard Marion steam shovel.

The gravel occupies a small hill in the forks of the in-going and out-going roads and appears to underlie at least 4 acres.

Section at gravel pit at entrance to Fort Benning

	Feet
Red clay and fine-pebbled gravel	3
Coarse clay gravel	3
Sandy clay and gravel	3–4

The gravel is used in gravel road construction in the reservation.

Rocky Creek.—On both sides of Rocky Creek from 20 to 40 feet above the stream on the old Lumpkin road 12 miles south of Columbus, large deposits of gravel occur. North of the stream on this road the gravel is composed of medium-sized quartz pebbles in a highly cemented clay matrix and has been quarried for road material.

Section north of Rocky Creek on Lumpkin road, 12 miles south of Columbus

	Feet
Hard, red, clay-gravel	5–6
Partially indurated stratified yellow clay	6
Coarse, clayey gravel	3

The cover increases toward the top of the hill and the thickness and extent of the gravel lenses is variable, although apparently continuous along the stream.

South of the creek on this road from 3 to 7 feet of solid gravel occur, having medium to coarse, well-rounded pebbles. The cover ranges from a few inches to 7 feet. Beneath the upper gravel, coarse sand and gravel at least 5 feet thick are found. The material is excellent for road building.

It is probable that gravel such as that described occurs on the first terrace overlooking Chattahoochee River along its entire course through the reservation and that it will be thicker and more extensive close to tributary streams.

CLAY COUNTY

No large deposits of commercial sand or gravel have been opened in Clay County, although small pits near Fort Gaines supply most of the local demand.

J. C. Sutton property.—A gravel pit has been opened on the Locofokee Road 1.8 miles north of Fort Gaines about 200 feet west of the road. The pit is near the top of a 25-foot hill and is about a tenth of an acre in extent and shows a loamy, pebbly cover 2 or 3 feet thick. The gravel ranges from 2 to 5 feet in thickness and consists of quartz, quartzite, and a few limestone fragments, generally rounded, and from a quarter inch up to 2 inches, with an average size of one inch. A clayey sand occurs with the pebbles which becomes more clayey near the bottom, until the underlying limestone is reached a few inches beneath the floor of the pit. Sample *T-212* from this pit shows a fineness modulus of 5.40 with 61 per cent of the pebbles retained on a 4-mesh screen. The pebbles are of sub-angular, fairly tough quartz or quartzite.

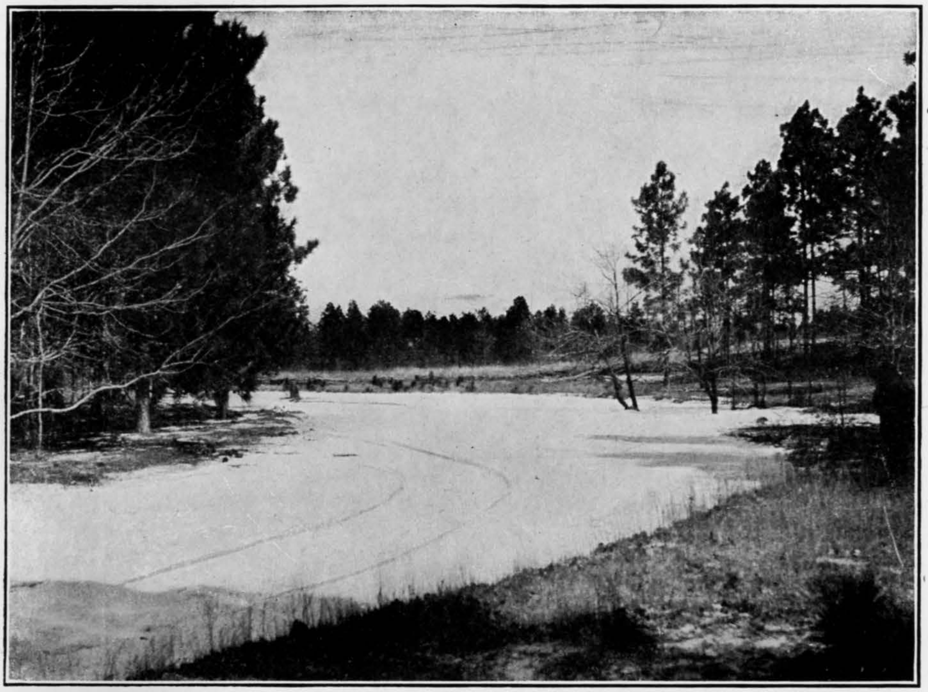
Gravel of similar character, but of uncertain thickness, caps another hill just west of the pit. A small knob about 200 yards south of this last hill shows, in the gullies, about 5 feet of sandy gravel covering the surface. It is concentrated near the base of the hill and probably a half acre is covered with good gravel to a maximum depth of 5 feet. A cut in the road 200 yards south of the pit shows 4 feet of clay gravel suitable for road material. Most of the depo its in this locality appear to be thin veneers only, very irregular and discontinuous in their extent. The Central of Georgia Railway is about a half mile east of these deposits.

Magruder Creek.—On the Eufaula-Fort Gaines road, 13 miles north of Fort Gaines, large quantities of excellent quartz gravel occur in Magruder Creek for several hundred yards north and south of the bridge. (Plate VIII-B). The creek channel is ordinarily about 30 feet wide, and the first bottom is from 100 to 150 feet wide and is covered with white sandy gravel ranging from 2 feet thick in the channel to as much as 6 feet further back. The pebbles are rounded to sub-angular and range from a quarter inch to 3 inches in size. The sand is well graded. Sample *T-225* shows a fineness modulus of 5.54 and has 57 per cent coarser than 4 mesh. This material was used in the construction of the hydro-electric plant on Pataula Creek one mile south of the deposit.

The bank of the first terrace overlooking the creek on the north shows the following section:

Section of bank on Magruder Creek just west of Eufaula-Fort Gaines road bridge

	Feet
Yellow clay overburden	3–7
Sandy, white to yellow gravel	8
Blue, green, and black clay	3



A. SAND STREAM, 1 MILE NORTH OF TAZEWELL, MARION COUNTY

B. DRAG-LINE INCLINE AND SCREENING PLANT, RUTLEDGE & CHESTNUT, BULL CREEK, 3 MILES SOUTHEAST OF COLUMBUS, MUSCOGEE COUNTY

Strata of this nature probably underlie, for some distance along the creek, the entire first terrace or second bottom which ranges in width from 100 to 200 yards. Northwest of the bridge as much as 12 feet of good sand-gravel lying between blue clay strata is exposed in the stream cut. At this point the cover ranges from one foot near the stream to six feet further back. The clay below has an irregular upper surface. The origin of both this gravel and that in the stream bed is due to the weathering, and subsequent deposition by streams, of a large deposit lying close to the stream and extending from a point half a mile below the bridge to two miles above it. Distance from rail transportation will probably prevent the use of these large deposits for some time.

F. M. Gay, Jr., property.—Just south of Magruder Creek on the Eufaula-Fort Gaines road and 25 feet above the bridge level, 10 feet of excellent sandy clay gravel shows in the road cut and has been used in the construction of the road. Streaks of sandy clay from 1 to 4 inches thick run through it, but the entire deposit will run 50 to 60 per cent pebbles over a quarter inch in diameter. It extends for 200 feet along the road and apparently is of considerable extent, covering at least 50 acres. The cover increases from a few inches to 10 feet near the top of the hill overlooking Magruder Creek.

On the same road 0.4 mile south, 4 feet of gravel outcrops in the road, and 0.2 mile north of Pataula Creek the same thickness of fine-grained sand-gravel is exposed in road cuts.

Gravel of this character usually occurs on the second terrace overlooking Chattahoochee River and is exposed by the creeks which cut through the scarp. It is usually all of similar nature and well suited for road building, although its remoteness from railroads is a hindrance to its present development.

J. C. Neeves property.—Seven miles from Fort Gaines on the Blakely road a few feet of sand and clay gravel show in road cuts at the top of a small hill. Very good but small deposits of gravel occur in Colomokee Creek and in its tributaries; and although the location is inaccessible for commercial purposes these and other deposits may serve for future use in the construction of concrete roads or bridges in this part of the county.

Edward King property.—One mile north of the Early County line, on the Fort Gaines-Blakely road, there is a small hill on which the sand and gravel does not exceed 3 or 4 feet in thickness.

CLINCH COUNTY

Sand, closely underlain by red and yellow clay, covers most of Clinch County; and at a greater depth the blue clays and clayey sands of the Alum Bluff formation are found.

Allapaha River.—The Satilla terrace continues along Allapaha River, but is not everywhere marked by deep sands. On the south side of a small creek, about 3 miles north of Mayday, in the southwest corner of the county on the Statenville-Stockton road, from 8 to 12 feet of fine-grained, irregularly stratified, clayey sand occurs. Surficial sand appears between this creek and Stockton ranging in depth from 2 to 10 feet, although it is so remotely situated as to be of no commercial value. Along the Atlantic Coast Line Railroad between Stockton and the river no sand of commercial value occurs.

Small bars and deposits of white sand, suitable for glass-making, occur in and along Allapaha River throughout its entire course along the western edge of the county.

In the northeast part of the county, near Arabia Church, a deposit of over 10 acres of pure white sand occurs suitable for glass-making, but distance from a railroad is likely to prevent development.

COFFEE COUNTY

The surface is covered largely with gray sand generally from a few inches to 3 feet in thickness and underlain by the usual yellow or red clay and sandy clay.

Seventeenmile Creek.—Seventeenmile Creek proves no exception to the general rule throughout South Georgia that the larger streams have deep sandy belts on their northern or eastern sides. This belt is very prominent near Douglas at the Atlanta, Birmingham & Atlantic and Georgia & Florida railway crossings, but it extends practically through the entire county from a quarter to three-quarters of a mile in width, and from 8 to 25 feet in thickness.

Just west of Chatterton on the Atlanta, Birmingham & Atlantic Railway, and 6¼ miles east of Douglas on the Nicholls road, J. J. Downing operates a sand pit. The pit has been worked at intervals since 1902, and about an acre has been uncovered. The working face is 400 feet long and the sand is from 20 to 25 feet thick. The following section is shown:

Section at J. J. Downing's pit, west of Chatterton

	Feet
Sandy soil with roots and vegetation	3
Rather loamy, yellow, gray sand	3
Pale yellow sand with red, clayey sand strata one-quarter inch thick and one inch apart. Most of this sand is rather fine-grained, sharp, and clean	13
Coarse, yellow sand, irregularly distributed over the pit	1
Shell of irregularly distributed, red, sandy clay, very hard, extends in streaks or occupies isolated spots	1
White, fine-grained sand with yellow strata through it, becomes pure white below	3

The sand is used in Douglas for concrete street paving, in Fitzgerald and other South Georgia towns, and in the foundries of the Atlanta, Birmingham & Atlantic Railway. Private tests showed it to contain one per cent of silt and the 7-day mortar test is said to have shown it to be 10 per cent better than standard Ottawa sand. (See *T-234*, table). Twelve hundred feet west of this pit, on the railroad, another ridge 8 feet above the grade makes favorable conditions for working the sand.

On the Georgia & Florida Railway, just east of its crossing of Seventeenmile Creek, similar sand occurs in the same wide ridge, from 8 to 20 feet thick. No sand is worked at this point, however. The Douglas-Broxton road runs through this part of the belt about 2½ miles north of Douglas.

On the Broxton-Barrows Bluff road, between Prigden and Dicky's Farm, several acres of coarse, gray sand up to 6 feet thick occur along the Georgia & Florida Railway. The probable extent of this coarse sand is small, but there appears to be plenty in this vicinity and, in fact, in the entire northern part of the county, for local use.

Ocmulgee River, bounding the county on the north, may be a future source of sand supply for construction work in that part of the county, but at present its large bars of coarse sand are accessible only to transportation by boat.

COLQUITT COUNTY

The surface of Colquitt County is covered with sand in the eastern part, but a light sandy loam is characteristic of the most of the rest of the county.

Moultrie.—The deposits from which Moultrie obtains its local sand are of poor quality, the sand being fine-grained and clayey and the deposits not extensive. Some loamy sand of poor quality occurs in a 5-foot bank east of Ocklocknee River, 1.3 miles west of Moultrie on the Camilla road, and in the river bed small deposits of a fairly good medium- to coarse-grained sand occur. On the Doerun road, 2½ miles northwest of Moultrie, a small pit has been worked on the Barber place. The sand here is loamy and the deposit usually less than 4 feet thick. A sample (*T-239*) from this deposit showed a fineness modulus of 1.34 and 41 per cent was retained on the 48-mesh sieve. The organic content gave a color value of 800.

Sand from the vicinity of Okapilco Creek, one mile east of Moultrie, on the Adel road, is also used locally. This sand is similar to that from the other sources. Between Moultrie and Thomasville there is practically no sand even for local use.

Little River.—On the Moultrie-Adel road west of Little River the following section is shown:

Section west of Little River on the Moultrie-Adel road

	Feet
Dirty, yellow, sandy clay and silty sand	6
Fine-grained, white sand	8 (?)

A sample of the white sand was analyzed to see whether it was pure enough for glass and the following results obtained:

Analysis of sand from Little River, Adel-Moultrie road. T-238

Lime (CaO)	0.00
Magnesia (MgO)	0.11
Alumina (Al_2O_3)	0.11
Ferric oxide (Fe_2O_3)	0.94
Silica (SiO_2)	98.62
Total	99.78

It is not known whether this white sand extends to the Georgia & Florida Railway crossing one mile to the north, but it is typical of the sand so generally seen in this part of the "wire grass" region along streams and in swampy areas. A coarser-grained, white sand, probably of small thickness, parallels the west side of the river a few hundred feet back from it.

COOK COUNTY

The surface of Cook County is sandy to a depth of from a few inches to several feet and is underlain by clays and sands of the Alum Bluff formation. Local accumulations of sand, particularly near branches, supply Adel, Sparks, and the other towns of the county with sand of fair quality for less important work. No sand hills occur east of Little River as was the case to the north in Tift County, either at the South Georgia or the Georgia & Florida railway crossings, although within the river small bars of medium-grained, white sand occur, and the river bed itself is composed of similar white sand.

On the Adel-Moultrie road considerable sand occurs, probably varying in depth from 3 to 10 feet, but it is not sufficiently thick or persistent to be of much commercial value.

CRAWFORD COUNTY

Immense quantities of commercial sand are produced annually in the county from a number of pits along the Southern Railway and shipped to every part of the state as well as to points in adjoining states.

The sand area of Crawford County forms a part of a belt extending with some interruptions from Richmond County almost to Columbus. It ranges from 2 to 6 miles in width, and the sand is from 5 to 30 feet thick. The surface is undulating, the thicker sand occuring usually where the land is highest. The valleys of the few streams cutting the area usually expose the underlying Cretaceous white clays, and in the shallower valleys, where the clay is not exposed, the sand is usually thinner but coarser than that on the hills and ridges.

McCarty sand pits.—Near the southeast margin of the sand belt, on the Southern Railway, C. C. McCarty of Fort Valley operates two pits on land leased from W. P. Carr. The southernmost pit is one and three-quarter miles north of Zenith and covers several acres. The face of the pit is about 18 feet high, the upper 5 or 6 feet of the sand being fine-grained and gray in color. (Plate IX-A.) The next 8 to 10 feet is reddish-yellow to brown and slightly coarser than that above although still fine-grained. Alternating clayey layers from ½ to 2 inches thick and layers of paler, cleaner sand, 2 or 3 inches thick, give a wavy or corrugated appearance to this portion of the face. The lower 3 or 4 feet of the pit is coarser and usually yellow. The sand is loaded on cars by hand labor with wheelbarrows and is shipped principally to Atlanta. Only one grade is produced. Sample *T-69* is representative of the pit and shows a fineness modulus of 1.90 with 72 per cent coarser than 48 mesh.

The second McCarty pit adjoins on the south that described above and occupies several acres. The face shows an average thickness of 18 feet of sand. The sand is similar to that in the other pit except that the coarser sand at the bottom is usually thicker, ranging from 4 to 6 feet, and consequently the sand from this pit is of better quality than that from the other. Sample *T-70* is typical of the lower part of the deposit, and shows a fineness modulus of 2.12, with 79 per cent coarser than 48 mesh.

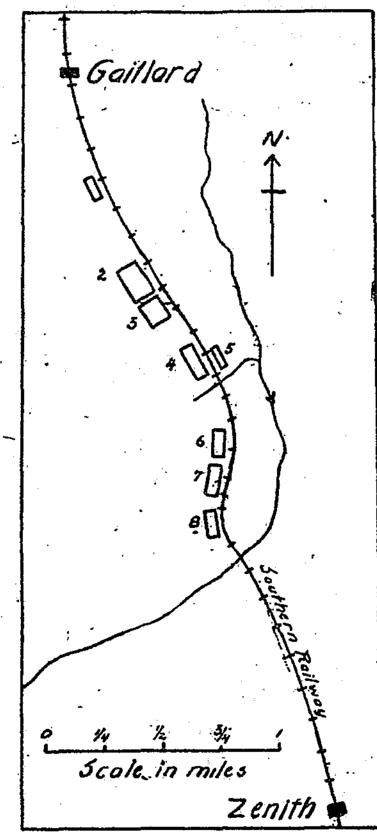


Fig. 12. Sand pits along Southern Railway between Gaillard and Zenith.
1, Smiley pit; 2 & 3, Atlanta Sand & Supply Co., Rollo pits; 4 & 5, Allon pits; 6 & 7, McCarty pits; 8, Spillers pit.

A large abandoned pit, formerly operated by L. A. Spillers of Gaillard, is located just south of the pit described above. The sand appears to be finer-grained and hence of poorer quality than that to the north. The color is reddish-brown and the clay content large. No sand has been shipped from this pit for a number of years.

Allon Sand Company. — Several hundred yards north of the McCarty pits the Allon Sand Company, managed by Mr. F. C. Chevis of Gaillard, owns 202½ acres and operates a pit just north of the Armour fertilizing plant.

This pit covers several acres, and the sand is approximately 11 feet thick at the present working face at the south end of the pit near the railroad, but it increases to 15 feet further west. This pit is rather remarkable in not having the stratified condition so apparent in the other pits in this part of the sand belt.

A 10-ton Buffalo locomotive crane with a ¾-yard clam-shell bucket and a 35-foot boom is used. (Plate IX-B.) A 50-ton car can be easily loaded in 1½ hours with this crane. The upper 4 feet is fine-grained, pale yellow and clean and is removed first and sold for brick and plaster mortar purposes. Below this a pale yellow, medium- to coarse-grained sand almost white in places and averaging 5 to 6 feet in thickness occurs. This sand is used throughout the state for concrete aggregate and has even been shipped as far as Nashville, Tenn. Sample *T-64* is representative of the concrete sand, and a granulometric analysis shows a fineness modulus of 1.59 with 52 per cent coarser than 48 mesh. The sand has only a slight trace of organic matter.

Beneath the concrete sand reddish-yellow clay is encountered. At the west end of the pit, where the sand is thicker, just above the clay from 18 inches to 2 feet of sharp, fine-grained, pale yellow to white sand, silky in texture, is found. This sand is in great demand by plate glass companies and marble finishing works for abrasive purposes. Sample *T-63a*, representing this abrasive sand, has a fineness modulus of 1.27 with 27 per cent coarser than 48 mesh.

Where the clean sand grades into the clay at the pit bottom, a clayey sand, making an ideal coarse molding sand, occurs, which is shipped to Savannah and Atlanta foundries, where it commands a good price. East of the railroad and opposite the Allon sand pit, the underlying red clay comes to the surface, but the sand content is high enough to make a coarse molding sand similar to that found at the contact of the sand and clay in the main pit. A small pit has been opened here and molding sand is shipped from it. Considerable fine-grained molding sand is said to occur along the creek a quarter mile east of the main pit.

Considerable prospecting has been done in this vicinity. Wells show as much as 18 feet of sand and more in places. A hole at a spring southwest of the pit showed 20 feet of white sand with a high kaolin content. Auger borings east of the railroad showed a large acreage of sand from 14 to 20 feet thick.

The cover of sandy soil and roots is being removed from this portion of the property to a depth of 2 feet by hand and loaded into one-yard dump cars hauled by a small dinky. Formerly a ladder wagon-loader was used to handle this sand, but due to rapid wearing of parts by the sand, which it is practically impossible to keep from the working parts, it is no longer used.

Atlanta Sand and Supply Company.—The Atlanta Sand and Supply Company, of Atlanta, owns over 400 acres of land along the Southern Railway and operates the Rollo sand pit north of the Allon sand pit. The face is several hundred feet long and the sand pale yellow to brown. The top of the main face is 25 feet above the track and the sand at the face 15 to 18 feet thick from the floor to the top. At the north end of the pit, the upper 5 feet is fine-grained and yellow and is underlain by from 1 to 4 feet of coarse clayey sand containing numerous sub-angular pebbles up to ½ inch in diameter. Beneath the coarse layer alternations of yellow and reddish fine and coarse sand with a rather high clay content occur from 8 to 12 feet. At the track level a mottled sandy clay shows. A Vulcan steam shovel having a ⅝-yard dipper has recently been installed, which loads the sand dry. A car can usually be loaded in 40 minutes with this machine.

At the north end of this pit the sand is mined by playing a powerful jet of water against the face which carries the sand down an inclined wooden sluice which was about 150 feet long when visited and had a 4 per cent slope. (Plates V-B, X-A.) The sand then passes through a $\frac{3}{16}$-inch screen and into the railroad car. The spur track was formerly on the up-hill side of the main line, but this has been moved to the other side of the main line to increase the fall from the pit face, the sand sluice passing beneath the main line. Temporary partitions are placed in the car permitting the sand from the sluice to be retained while the water runs off carrying some of the silt and clay with it. The water is pumped through an 8-inch pipe first and then through a 5-inch pipe from a pond produced by damming a small stream about 130 feet vertically below the pit. From the 5-inch pipe the water passes through a 1½-inch nozzle directly striking the face of the pit at the rate of 500 gallons per minute. No attempt is made to clear away the surface vegetation before jetting. The entire system is about 1,100 feet long. The pump is 12 x 10 x 24 inches. By this method only three men are required, one to take care of the pump, one at the face to handle the hydraulic jet, and one in the car being loaded. A car of 30 to 40 tons capacity, either of the gondola or box type can ordinarily be loaded in an hour and a half. At the same time the sand is partially washed and the twigs and foreign matter screened out.

Sample *T-61* was taken from the upper part of a car being loaded at the time of the writer's visit. The sand is pale yellow, clean, and has a fineness modulus of 1.88 with 68 per cent coarser than 48 mesh. The color value of the organic content was 100. Concrete strength ratio tests made by Prof. F. C. Snow at the Georgia School of Technology on sand from this pit showed 143 and 120 per cent at 7 and 28 days, respectively.

A chemical analysis of the natural sand from this pit was made and its results typify the chemical character of most of the sand in the Fall Line sand-hill belt.

Analysis of natural sand from Atlanta Sand and Supply Company's pit, Gaillard, Georgia

Loss on ignition	1.04
Soda (Na_2O)	trace
Potash (K_2O)	trace
Lime (CaO)	.00
Magnesia (MgO)	.00
Alumina (Al_2O_3)	1.09
Ferric oxide (Fe_2O_3)	0.72
Titanium dioxide (TiO_2)	0.19
Silica (SiO_2)	96.90
Rarer earths	0.00
Total	99.94

A partially worked-out pit adjoins the present workings on the north and about a mile south of Gaillard. According to Mr. J. C. West, former superintendent of the pit, there is a total thickness of 30 feet of sand here, 15 feet of which lies below the track level and consequently can not be recovered at present. The sand is fairly uniform throughout with only slight traces of stratification. Sample *T-62* represents an average sample of the natural sand taken over a vertical distance of 8 feet about 10 feet below the top of the pit. A mechanical analysis showed a fineness modulus of 1.98 with 66 per cent coarser than 48 mesh. The organic content showed a color value of 40.

A typical section of the strata underlying the property is shown in the record of an auger boring furnished by Mr. West and made a short distance back of the pit face.

Section in boring at Atlanta Sand and Supply Company's pit, Gaillard, Georgia

	Feet	Inches
Yellow, fine- to medium-grained sand	12	
Kaolin	1	
Fine yellow sand		10–12
Fine white sand		0–18
Red clay	2–3	
White clayey sand	1	

Smiley Sand Company.—The Smiley Sand Company, of Atlanta, has leased 13 acres of sand land from W. P. Carr along the Southern Railway about a half mile north of Gaillard. A pit was opened in 1919 and a travelling derrick with a 30-foot boom and a Rawson ¾-yard clam-shell bucket was installed. A 35-horsepower Lidgerwood hoisting engine is used. The pit is worked by making a narrow cut about 40 feet wide for the length of the property; from 6 to 8 cars can be loaded at one setting of the derrick and then the outfit is moved back about 15 feet. Four men are employed.

Section at pit of Smiley Sand Company, Gaillard

	Feet
Sandy soil with roots	1
Yellow to brown, fine-grained sand	5
Medium-grained, pale yellow to yellow-brown, faintly stratified and having irregular streaks and small splotches of clayey sand	7
White, hard, micaceous, fine- to medium-grained sand	3
	16

The white sand is not usually loaded as it is hard to loosen with the grab-bucket in use. Beneath the white sand a red and yellow sandy clay with lenses of white clay occurs.

Mills property.—The Mike Mills property lies north of the Roberta-Gaillard road and west of the railroad, but that part of it containing sufficient sand to work lies almost half a mile from the railroad.

At Gaillard a small pit was formerly worked east of the track, a few hundred feet south of the road. Sand somewhat finer than that further south occurs here. North of Gaillard the red clay comes so close to the surface in the area directly adjoining the railroad as to prevent the commercial use of the sand, except over small areas.

Harrison property.—On the Ella Harrison property, along the Southern Railway, 1 mile north of Roberta, a half acre sand pit has been opened, and sand has been shipped to various points. The material is very fine-grained and about 7 or 8 feet thick over several acres. The sand is not stratified and is underlain by the usual red and yellow clay. Sample *T-67* is typical of the deposit and shows a fineness modulus of 1.53 with 51 per cent coarser than 48 mesh and has only a trace of organic matter.

GRAVEL

Roberta-Reynolds road.—Three miles southwest of Roberta, three feet of clay gravel with tough quartz pebbles from ¼ to 2 inches in size outcrops along the road for almost a quarter of a mile. The gravel is associated with irregular layers of coarse sand and fine gravel in red clayey sand and has been used in road construction for which it is fairly well suited.

Four miles from Roberta, southwest of a small branch, the sand belt begins and extends for some distance along the road. The cuts show up to 7 feet of sand underlain by red clay. Further west the material becomes coarser.

Flint River.—On the Crawford County side of Flint River, 1,000 feet back from the channel, a coarse bouldery gravel of tough quartz pebbles was noted along the Reynolds-Roberta road. The thickness does not appear to exceed 2 to 3 feet, although detailed work along the river from this point may disclose workable deposits. Gravel is said to extend up and down the river from this point for three fourths of a mile occurring mostly on the J. M. Walker property.

Roberta-Macon road.—On the edge of Knoxville along both the Columbus and Byron roads, three thin layers of clay gravel from 1 to 1½ feet thick separated by 1 or 2 feet of clay with rounded granular quartz pebbles ranging from ¼ inch to 3 inches in diameter, are found. The deposit is small and is used for local road building.

On the Macon road 4 miles from Knoxville, thin surficial gravels occur from 1 to 1½ feet thick. The gravel outcrops in the road cuts overlying schist and caps the tops of some of the surrounding hills. Eight and a half miles from Knoxville on the same road, similar thin gravel layers are found in the Lower Cretaceous strata in the road cuts.

Other deposits.—In the northern part of the county which is underlain by schists, gneisses, and granites, the sand and gravel supply is restricted to the beds of the streams. Most of the streams have deposits of good coarse-grained sand and some gravel with the quartz content ranging from 75 to 95 per cent of the material.

CRISP COUNTY

No sand is produced commercially in Crisp County, although Flint River which forms the western boundary of the county has large, but rather inaccessible deposits. Throughout most of the county a surficial deposit of gray to yellow sand occurs ranging from 1 to 4 feet in thickness. Such sand is very fine-grained and generally loamy and consequently of little value except for unimportant local work. When concentrated in ditches or along streams it is cleaner and coarser, usually yellow, and generally forms the supply for local work not demanding a high-grade sand.

Flint River.—Numerous bars of medium- to coarse-grained brown sand in Flint River point to a large supply should the demand warrant the expense of installing a pump and other necessary equipment to recover it. The most favorable place for pumping would be near the Seaboard Air Line Railway crossing west of Daphne.

DECATUR COUNTY

Aside from the use of sand in the manufacture of concrete brick at the plant of the Decatur Concrete Works at Bainbridge neither sand nor gravel is exploited commercially in Decatur County. Large quantities are found east of Flint River near Bainbridge, and also near Faceville. This sand is fine-grained, pale yellow, and suitable for a plaster or brick mortar Sample *T-220* taken from similar deposits east of Flint River and opposite Newton, in Mitchell County, has a fineness modulus of 1.63 and 59 per cent coarser than 48 mesh. At Faceville the sand is buff and has a large amount of organic matter.

Fine- to medium-grained sand occurs in Spring Creek, and at Brinson small deposits of white, fine-grained sand occur west of the stream on the Jakin road.

Chattahoochee River, forming the western boundry of the county, has enormous amounts of medium-grained sand, suitable for local construction work, but not likely to be commercially developed for some time,although the Atlantic Coast Line Railroad crosses the river west of Saffold.

Decatur Concrete Works.—The plant of the Decatur Concrete Works is located opposite the Georgia, Florida & Alabama Railroad depot at Bainbridge. Various articles of concrete are manufactured here including pressed concrete brick. The sand is obtained from a pit along the Atlantic Coast Line Railroad just east of the bridge. This sand is yellow and somewhat fine-grained, the deposit covering several acres. Sand is also obtained between the depot and the river and about an eighth of a mile behind the plant. The sand here is coarser than at the other deposit, the particles ranging up to a half inch in size and are freer from loam. The sand from the pit is mixed with cement in the proportion of 1 to 3 or 1 to 4, according to the quality of the brick desired, together with a small amount of water to enable the mixture to be molded. The mix is then molded into bricks in a Helm press and the bricks are then placed on racks under cover to harden. The capacity of the plant is about 12,000 bricks a day.

DODGE COUNTY

Surficial leached or wind-blown sand covers most of Dodge County from a depth of a few inches to several feet. No deposits of sand are worked commercially in the county, although Ocmulgee River has large deposits, and bank sand also is found north of Gum Swamp and other creeks.

Eastman.—A deposit of buff to yellow, fine-grained sand similar to that found east of Helena, occurs east of Little Ocmulgee River (Gum Swamp Creek), three and a half miles east of Eastman. Where the Eastman-Dublin road crosses the deposit, it is about 1000 feet wide, and from 5 to 10 feet thick, beginning 500 feet east of the creek. A red, clayey sand belonging to the Atlamaha formation underlies the yellow sand. Near the creek white sand, possibly suitable for glass, is exposed beneath the upper yellow sand. Neither the thickness nor the extent of the white sand could be determined, but it indicates that the sand occurring along this stream at Lumber City and, also outcropping east of Helena, is probably continuous along most of the stream's course. This sand is used for local building purposes in Eastman.

Ocmulgee River.—Ocmulgee River, forming the southwest boundary of Dodge County, has many bars of medium- to coarse-grained brown sand, well suited for concrete purposes. The only point accessible to rail transportation is at the Seaboard Air Line Railway crossing between Rhine and Abbeville, elsewhere the use of boats will be required in case the demand warrants the pumping of the sand.

Peacock property.—Thin, irregular patches of gravel are found on the J. Peacock plantation, west of the Dublin road. No deposits more than 2 to 2½ feet thick were seen. The gravel is sandy and the pebbles, which are of angular quartz, range in size from a quarter inch to 2 inches. This gravel has few commercial possibilities, although it has been used in concrete construction at Eastman.

Low property.—Several small deposits of sandy gravel occur on the Thomas Low plantation, 4.7 miles from Eastman, on the Cochran road. The pebbles are of angular to sub-angular quartz and attain a maximum size of two inches. Several deposits occur on the property, generally an acre or two in extent, and probably under 2 feet in thickness. The upper 8 or 10 inches of the gravel is scraped up and has been hauled to Eastman and other points for building and road purposes.

Near Gresston, along the Seaboard Air Line Railway, and near Empire, along the Seaboard Air Line and Wrightsville & Tennille railroads, gravel occurs generally under 2 feet in thickness and of only local value. The Gresston deposit occupies an irregular area northeast of the railroad and extends roughly parallel to it for almost 2 miles. A sample obtained from a small deposit at Gresston is characteristic of the many areas of this type of sand in the county. Twenty-five per cent was retained on 10 mesh and 15 per cent was silt and clay. The fineness modulus is 2.52.

Other deposits.—A number of isolated areas of coarse, yellowish-white, gravelly sand occur in the county, similar to that near Gresston. The largest areas of this type occur at the heads of some of the creeks flowing into Ocmulgee River, in the western part of the county, notably Cypress River, Mosquito Creek, and other smaller creeks. A deposit covering over 100 acres occurs about 5 miles east-northeast of Eastman. A smaller area lies a half mile northwest of Beehive in the northeast part of the county, and a still smaller deposit is located just east of Chester, on the Wrightsville & Tennille Railroad, in the northern part of the county.

DOOLY COUNTY

The western half, and a strip across the northern part of Dooly County, is underlain by Ocala limestone, expressed on the surface by the characteristic red and gray residual clayey sands and clays and some limestone outcrops. The remainder of the county is covered with mottled clays and sands of the Altamaha formation which in places is indurated. No commercial sand is produced in the county, and few deposits of even local value occur, although Flint River has larger supplies, but these are usually inaccessible.

A somewhat fine-grained gray sand occurs along Flint River and is suitable for most construction purposes. A sample of sand of this type obtained at Murray's Ferry, 11 miles west of Vienna, was tested by the U. S. Bureau of Public Roads and found to produce concrete having a tensile strength of 90 per cent of that made from standard Ottawa sand. This sand contained 0.4 per cent of silt and a little organic matter.

Mechanical analysis of sand from Murray's Ferry

	Per cent retained on following mesh sizes:								
Mesh size	10	20	30	40	50	80	100	200	200
Percentage	0.4	9	35.2	29.2	16.6	7.0	1.0	1.0	0.6

DOUGHERTY COUNTY

The sand deposits of Dougherty County are restricted mostly to the vicinity of Flint River. An extensive sand hill deposit occurs along the river just opposite Albany, and smaller deposits occur in and along tributary streams.

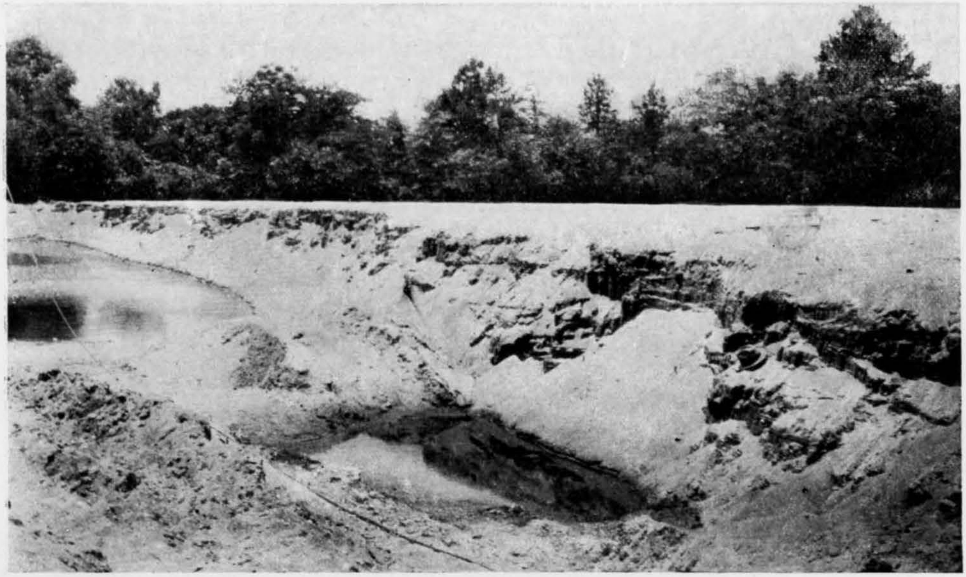
Albany.—Tift Hill is the local name given to a rolling, sandhill area lying east of Flint River opposite Albany, and to the south and west of the Atlantic Coast Line Railroad. Over 400 acres are here underlain with fine- to medium-grained, yellowish, clean sand, ranging in thickness from 10 to 40 feet.

Albany Sand, Lime and Cement Company.—A pit has been operated for some time on the north side of Tift Hill, 1.6 miles east of Albany on the Atlantic Coast Line Railroad. The pit occupies about 2 acres, and the face is from 5 to 20 feet high. The sand is very uniform throughout the pit both vertically and laterally, although a slight increase in grain size and a decrease in color is noticed toward the bottom of the pit. The usual clayey sand strata are lacking in this deposit, only faint lines of slightly darker sand, a few grains in thickness, being noted. The sand is loaded on cars with wheelbarrows and shipped to various points throughout South Georgia. From 2 to 4 cars daily are usually loaded. A sand dryer for drying sand for use in locomotives has been built. The dryer consists of a furnace around which a compartment has been built of sheet iron capable of holding about 10 cubic yards of sand. An elevator is fed from an opening in the dryer so that the dried sand can be elevated to a bin above, from which cars or locomotives can be loaded. The sand here is similar to that represented by sample *T-210,* which has a fineness modulus of 2.02 and 88 per cent coarser than 48 mesh. It has practically no organic matter.

Sand extends along the Atlantic Coast Line Railroad in both directions, and small pits for local use have been opened at several points. Three tenths of a mile west of the large pit on the Albany road, a smaller pit covering a few thousand square feet with a face from 12 to 15 feet high, is operated.

Tift Silica Brick Company.—The Tift Silica Brick Company, Mr. A. S. Bacon of Albany general manager, has a large sand pit at Albany Junction on the Atlantic Coast Line Railroad 2¼ miles southwest of the Albany court house. The pit covers several acres, and the exposed face ranges from 15 to 30 feet in height. The sand is pale yellow, composed entirely of quartz, and is remarkably clean and uniform. Faint stratification lines dipping from 30° to 40° to the eastward and consisting of slightly coarser grains in layers ¼ inch thick and with from 2 to 6 inches between the layers, occur in the lower two thirds of the deposit. Practically no silt or clay is in the sand, although the clay substratum is exposed in places in the pit floor. The undulating topography of the sand hill, visible from the top of the pit banks, consists of small hills reaching a maximum of 40 feet above the railroad grade with intervening valleys or depressions where the clay appears to come very close to the surface. Sample *T-210* from this pit has a fineness modulus of 2.04 and 88 per cent is retained on the 48-mesh sieve. Only a trace of organic matter occurs.

The sand from the pit is used in the manufacture of sand-lime bricks which are said to compare very favorably with clay brick in strength and price. The sand from the pit is shoveled into a tram-car hauled by a small electric locomotive which deposits it on a bucket elevator by which it is delivered to a bin in the upper part of the brick plant. The sand is fed from this bin to a short belt conveyor from which an arbitrarily regulated portion (usually 15 per cent) is removed by a scraper and allowed to pass into a tube-mill where it is thoroughly ground and mixed up with the caustic lime which forms the binder. The tube mill is 5 by 22 feet and made by the Power & Mining Manufacturing Company. The sand and lime are ground until 90 per cent of the mixture passes 200 mesh, and it is then mixed with the rest of the sand which was carried along the belt conveyor beyond the tube mill. It is first mixed dry and then goes to a pug mill where enough



A. EXCAVATION BY DRAG-LINE ON BULL CREEK SAND AND GRAVEL BAR, RUTLEDGE & CHESTNUT PLANT, 3 MILES SOUTHEAST OF COLUMBUS, MUSCOGEE COUNTY

B. FACE OF MUSCOGEE COUNTY ROAD GRAVEL PIT, 3½ MILES EAST OF COLUMBUS water is added to hydrate the caustic lime. After thorough mixing it is raised by means of a bucket elevator to the top of a silo divided into two equal parts of 100,000 pounds capacity each. The mixture is emptied into one of the halves where it remains for 24 hours. Each day one half of the silo is being filled and the other half is being emptied. The sand-lime mixture is conveyed from the silo after moistening with sufficient water to give it good pressing qualities, to a Jackson & Church rotary brick machine, having 12 molds and a daily capacity of 28,000 bricks, where it is submitted to 10,000 pounds pressure per square inch. As the bricks are taken from the rotating molds they are piled on steel trucks and then wheeled into the steam cylinder which is 72 feet long and 6 feet wide. When the cylinder is full of bricks it is closed and live steam led in and brought to a pressure of 135 pounds per square inch and maintained for 10 hours after which the bricks are removed and ready for shipment.

At the time of inspection in the summer of 1919, a 150-horsepower outfit of the Buckeye Engine Company was used. The plant has since been electrified. About 110 horsepower is required to operate it.

The capacity of the plant is about 22,000 bricks daily. The product is a smooth brick, white to pale cream in color, having an absorption of 14 per cent and with a crushing strength of 3200-3700 pounds per square inch and a transverse strength, or modulus of rupture, of 450 pounds per square inch. The bricks are sold principally throughout South Georgia.

Muckafoonee Creek.—On the terrace west of Muckafoonee Creek, 800 feet northeast of the Georgia-Alabama Power Company's dam, excellent coarse sand has been deposited to a depth of a foot or two and is used for local construction work. At this point the creek bank shows the following section which may be typical of the bank for a very short distance, although the lower sand is of such good quality that it would seem desirable to test the deposit to determine its extent and thickness of the cover.

Section on Muckafoonee Creek near Flint River

	Feet
Flood-plain sand deposit, fine to coarse	½–1½
Fine-grained yellow to red sand	4 –7
Coarse, gritty, sharp, pale yellow, excellent for concrete and overlying the Ocala limestone	5 –6

Other deposits.—Sand somewhat similar to that at Tift Hill occurs in a much smaller deposit on the Georgia Northern Railway, 800 feet east of Flint River, opposite Albany. The deposit extends for 400 feet along the track and ranges from 8 to 10 feet in thickness; to the north, however, the tongue which crosses the railroad widens out into an area of about 75 acres. Along the track to the southeast the sand merges into a red, clayey sand. The deposit has not been worked.

Very little sand occurs along Flint River at the upper terrace level, south of Albany to the Mitchell and Newton county lines. On the first terrace, good coarse sand is found in a few places, but usually a fine-grained loamy material, possibly suitable for molding purposes occupies the flood plain.

EARLY COUNTY

No sand is produced for shipment in Early County, and small pits generally supply the local demand.

Underwood property.—Gullies have exposed a medium-grained yellow to white sand on the John Underwood property along Mill Creek on the Bluffton road, a little over a mile north of Blakely. A small pit has been opened in the gullies, and over 400 wagon-loads have been hauled to Blakely for local use. The good sand is at least 5 or 6 feet thick and is stratified. The lower part is white, and the upper part is discolored by clay carried from above by water. From 5 to 11 feet of red, sandy clay covers the desirable sand, so that extensive operation of the deposit must be made in a narrow strip close to the creek where the cover is at its minimum thickness. At present the sand is obtained by removing it from under the covering of sandy clay, and then removing the cover to worked-out parts of the pit after it has fallen in. Sample *T-211* shows a very uniform-grained sand having a fineness modulus of 2.15, with over 99 per cent retained on the 48-mesh screen. The color is orange, and the grains are of rounded and sub-angular quartz, highly stained with clay and iron oxide. The organic content shows a color value of 700.

Buchannon property.—Mr. W. A. Buchannon owns land on the opposite side of the creek from Mr. Underwood, and the conditions affecting the sand deposit there are practically the same. A sample from this property analyzed by Dr. Edgar Everhart gave the following results:

Analysis of sand from W. A. Buchannon property, Blakely, Ga.

Loss on ignition	0.38
Lime (CaO)	0.24
Magnesia (MgO)	0.12
Alumina (Al_2O_3)	0.39
Ferric oxide (Fe_2O_3)	0.14
Manganous oxide (MnO)	0.00
Titanium dioxide (TiO_2)	0.09
Silica (SiO_2)	98.41
Total	99.77

This sand is very pure and is suitable for glass. The extent of the deposit is apparently large, but the distance from a railroad (three-quarters of a mile), and the inconvenience of working the deposit due to the thick overburden over most of it are disadvantages that must be considered.

Further east along Mill creek on the property of Wm. J. Davis, a white sand of unknown extent and thickness and apparently suitable for the manufacture of the cheaper grades of glass occurs.

Considerable sand is found at Everett's Mill pond northeast of Blakely, but the cover here is thick. It is possible that detailed prospecting may show deposits of good sand close to the railroad along this same creek where the overburden is less.

ECHOLS COUNTY

Echols County is practically flat, poorly drained, and covered almost entirely with sand to a depth of from a few inches to several feet which becomes thicker on the terraces along Allapaha and Suwanee rivers. No commercial sand is produced in the county, although thick deposits occur near Statenville on the east side of Allapaha River.

Statenville.—The town of Statenville is built on the sand hills of the Satilla formation bordering Allapaha River on the east. This sand is from 10 to 15 feet thick on the Valdosta road just above the bridge, and the belt is from 200 to 300 feet wide and extends up and down the river from this point for several miles. The sand is fine-grained and somewhat clayey except about 8 feet below the surface where a coarser cleaner sand from 2 to 3 feet thick usually occurs. The character of the deposit can be easily seen in the gullies just south of the road. *T-242*, taken from the road cut, just east of the bridge, shows a fineness modulus of 1.54, and 50 per cent coarser than 48 mesh. The color value of the organic content is 125. The grains are of angular or sub-angular quartz and slightly coated with clay and iron oxide.

Sand of similar character and thickness is encountered in the Stockton road in Statenville just south of Troublesome Creek. A strip of sand 200 feet wide and from 6 to 8 feet thick occurs on the south side of the same creek where the Statenville Railway crosses it.

A chemical analysis of sand collected by Otto Veatch from the terrace above Allapaha River just north of Statenville gave the following results:

Analysis of sand from Satilla terrace at Statenville

Loss on ignition	.44
Ferric oxide (Fe_2O_3)	.17
Titanium dioxide (TiO_2)	.18
Silica (SiO_2)	97.89
Undetermined	1.32
Total	100.00

The sandy belt continues along the river intermittently to the northern part of the county, but it is practically absent at the Georgia & Florida Railway crossing at Mayday.

EFFINGHAM COUNTY

White and yellow sand ranging from a few inches to several feet in depth and underlain by clayey sands and clays covers a large part of the northern three-quarters of the county, and in the southern part of the county gray Pleistocene sands appear on the surface. No sand pits are operated in the county on a commercial scale, although unlimited sand is afforded in the bars of Savannah River, and considerable quantities occur along the east side of Ogeechee River and in the river itself.

Savannah River.—Sand deposits along Savannah River are of two types. (1) Sand which forms bars in the stream bed. This sand is dredged further down the river, a few miles above Savannah, and is representative of the sand in the river in the vicinity of Effingham County. The sand is medium- to coarse-grained, uniformly graded, and suited for concrete work (see *T-35* in table). The sand can be recovered by means of centrifugal pumps or dredges and loaded on barges or else put on board cars at the Seaboard Air Line crossing north of Clyo. (2) Sand deposits which cap the bluffs overlooking the river consist of the Pleistocene terrace deposits. At Parachuchla Bluff, 55 miles above Savannah, 15 feet of gray to pale yellow sand, without indication of stratification, is exposed. Such sand, so far from rail transportation, will probably not be utilized for a long time.

Ogeechee River.—Deposits of gray and pale yellow sand forming the Satilla terrace occur along Ogeechee River in Effingham County. At Eden the sand is exceptionally prominent and has commercial possibilities. Sand (sample *T-251*) on the property of C. F. Highsmith, west of Eden, is said to cover over 100 acres and range from 10 to 20 feet in thickness. The highest part of this sand hill is about 20 feet above the swamp. The sand has a fineness modulus of 1.77 with 66 per cent retained on the 48-mesh screen. It has practically no organic matter or clay.

Within the bed of Ogeechee River, for its entire course along the county border, are excellent deposits of white coarse gravel and some sand, ranging from one to four feet thick. This gravel was used in the construction of the bridge over the river on the Dixie-Overland Highway.

Other deposits.—Two miles south of Guyton, in the northern part of the county, the Central of Georgia Railway cuts through from 3 to 5 feet of fine-grained sand for about 800 feet. Between Ivanhoe and Guyton, along Ogeechee River, very little sand is exposed. Surficial fine-grained sand from 1 to 4 feet in depth characteristic of the county is exposed along the railroad between Guyton and Egypt.

EMANUEL COUNTY

Large quantities of sand and many small deposits of gravel occur throughout Emanuel County, associated especially with the streams, but none are now being utilized although formerly some were worked.

Swainsboro.—Local sand is easily obtained from the gullies and branches close at hand. On the Tye farm, 1 mile south of Swainsboro on the Tom road, a road cut and gullies show 5 feet of gravel, the upper 18 inches of which is a sand gravel. The pebbles are of white, sub-angular quartz up to 2 inches in diameter. The gravel shows for 300 feet along the road and appears to underlie with little cover 15 acres in the fields to either side of the road, along a small creek. The gravel would make an excellent road-surfacing material.

Corsey property.—Gravel covers a large acreage on the R. W. Corsey property, 5 miles from Swainsboro on the Tom road. Although the gravel has the appearance of great depth and thickness, only 1 foot was found in the well of a tenant house, 800 feet north of the road. The gravel is most prominent at and near the hill tops. It is likely that the gravel occurs in several thin layers from a few inches to a foot in thickness with from 3 to 10 feet of clay between and also that the concentration of the sand and gravel by the washing out of the clay has given it the appearance of great thickness. Sample *T-50*, typical of this deposit and most surficial gravel deposits in the county, has a fineness modulus of 7.46 and 84 per cent coarser than 4 mesh.

From the Corsey property and to within a mile of Tom on the Wadley Southern Railroad, fine- to medium-pebbled gravel shows at many places along this road. At no place was a thickness exceeding 4 feet noted, such material however, can be used with little trouble in surfacing local roads.

Blun.—At Blun, on the Georgia & Florida Railway, on the property of G. W. Wiggins, 600 feet west of the railroad, one or two acres are underlain with from 1 to 4 feet of clay gravel suitable for surfacing roads. The deposit has a cover of about a foot of sand and clay. In 1908 a small pit was opened, and a few carloads were shipped to Savannah for road building. The deposit, however, did not prove extensive enough for large shipments.

Adrian.—Numerous thin deposits of gravel and coarse sand occur near Adrian along the Wrightsville road and along Ohoopee River, both on the terrace hills overlooking the stream, or as concentrations in the stream. These terrace deposits continue down the river to Norristown where thin deposits are also abundant. Two miles east of Adrian in a cut of the Central of Georgia Railway, 2½ feet of clay gravel outcrops overlain by 8 feet of clayey sand.

On the Nunez-Vidalia road, 0.7 miles south of Nunez, from 1 to 3 feet of irregular clay gravel outcrops for 75 feet. It is not believed that the deposit is extensive as little evidence of gravel could be found in wells in this vicinity.

Canoochee River.—A thick belt of sand extends along the east sides of Canoochee River and Little Canoochee River, throughout most of their courses in the county. At the Georgia & Florida Railway (Millen branch) crossing of Canoochee River, south of Wade, the sand is white, clean, fine- to medium-grained and ranges from 10 to at least 15 feet in thickness. The belt at this point is about a quarter of a mile wide.

Ohoopee River.—The sand belt which extends east of both Ohoopee rivers in this county is not so well exposed as that east of Canoochee River. Where the main line of the Georgia & Florida Railway crosses Ohoopee River about 6 feet of medium-grained, gray to yellow sand is exposed for 500 feet. At the crossing of this river by the Millen branch of the Georgia & Florida Railway, the sand exposed is from 5 to 10 feet thick, and the cut 500 feet long. The sand here is finer than that further northwest.

East of Little Ohoopee River near Covena, is a belt of fine-grained sand, similar to that further east, 1000 feet wide and of unknown thickness. The Central of Georgia Railway passes through a low part of of the belt and only 5 or 6 feet of sand shows in the cut, although larger amounts occur 1200 feet north of the track. On the Vidalia-Nunez road the Ohoopee sand belt is from a quarter to a half mile wide north of the stream and at least 10 feet thick.

Pendleton Creek.—At Pendleton, on the Georgia & Florida Railway, east of Pendleton Creek, the sand belt along this stream is well exposed in the cut which shows 12 feet of yellow, fine-grained sand east of the track and 15 feet west of the track. The belt here is about 900 feet wide. The lower 2 feet of the sand, just above a reddish-yellow clay, is almost pure white. The sand extends eastward about 1 mile, but only 1200 feet westward in this vicinity. Most of this land is controlled by Benjamin Morris of Vidalia. The Georgia & Florida Railway dries this sand for locomotive use. The sand is dried in a small conical shaped drier, holding about 2 cubic yards at a time, and built around a stove. Holes 1½ inches in diameter are punched in the bottom of the drier close to the furnace, and the sand when sufficiently dried falls through these holes. About half an hour is required to thoroughly dry a batch of sand.

On the Norristown-Soperton road the Pendleton Creek sand belt is 800 feet wide over which distance it is at least 8 feet thick.

Other deposits.—A narrow belt of fine-grained sand lies east of Yamgrandree Creek. Along the Vidalia-Nunez road it is from 5 to 12 feet thick, the lower 2 feet being pure white. This belt is also crossed by the Central of Georgia Railway west of Nunez. Many other streams in the county have less extensive belts of sand along their eastern and northern borders.

EVANS COUNTY

Evans County is covered almost entirely with thin sand underlain by red and yellow clay at depths of from a few inches to several feet. No commercial sand pits are operated in the county, although a number of deposits of fairly good sand are exposed in different parts of the county, particularly along Canoochee River.

Canoochee River.—The sand belt bordering the east side of Canoochee River does not nearly attain the magnitude of that east of Ohoopee River, in Tattnall County, but it is of the same character. (See p. 250). Deposits of the sand are exposed in a belt from a quarter to a half mile wide extending south from a point near the Seaboard Air Line Railway, east of Daisy, almost to the Liberty County line. A deposit covering about 50 acres of medium-grained sand that is possible of exploitation occurs on the railroad just above Bull Creek.

Other deposits are exposed along the river near Mount Pleasant Church, 3 miles northeast of Claxton, and in smaller quantities and thicknesses along Bull and Cedar creeks.

Bars of white sand occur in the bed of Canoochee River throughout most of its course through the county. The sand is pure enough for bottle glass, but is difficult to recover without considerable expense.

GLASCOCK COUNTY

No commercial deposits of sand or gravel occur in Glascock County, although surficial sand is widespread, and small deposits of gravel and coarse sands are known near some of the streams.

Gibson.—One mile east of Gibson, along Rocky Comfort Creek, near the English bridge, deposits of fairly coarse, quartz sand are found. This material is used locally in Gibson for concrete purposes.

Gray, fine-grained, surficial sand ranging from a few inches to 6 feet in thickness is widespread over the county, but it is of very little value except near streams where a coarser grade of sand is generally found. Numerous gravelly spots occur, especially in the northern part of the county, but none of them are of any value except possibly for local road use.

GLYNN COUNTY

Most of Glynn County is a flat, poorly drained terrace lying a few feet above the sea and covered to a large extent with fine sand. Yellow and white, fine-grained sands lie on the surface near the coast and on the islands, but to the west in the swamp areas, considerable clay occurs with the sand. No commercial deposits of sand are operated in the county, nor were any deposits noted likely to be of commercial value. On the western edge of the county from Coleridge south to Little Satilla River, a sand-hill belt occurs probably containing the best sand in the county, but it is too remote to be of any value.

St. Simon Island.—Black sand has been found by S. W. McCallie on St. Simon Island, and it is believed that commercial exploitation may be possible. A detailed description of these deposits is given on p. 377.

GRADY COUNTY

One small deposit of sand in Grady County is being worked south of Gradyville on the Pelham & Havana Railroad. Elsewhere sand deposits are confined to the bed and sides of Ocklocknee River, which flows through the southeast part of the county.

J. A. Parrish pit.—A small pit has been opened at Parrish's sawmill, on the Pelham & Havana Railroad, 1½ miles southeast of Gradyville, west of Big Tired Creek. The pit covers about a quarter acre and is 300 yards from the creek and about 30 feet above it. The sand is shoveled into wheelbarrows and wheeled to the cars.

Section at Parish's Mill sand pit

	Feet
Soil, dark gray and sandy	1–2
Fine-grained, yellowish-gray sand	1–1½
Almost white, fine-grained sand, with a few quartz pebbles up to $\frac{3}{16}$ inch, with wavy layers of brown, sandy clay ½ to 1 inch thick and occurring at intervals of from 2 to 8 inches	3
White and yellow, well-graded sand, clay layers not so prominent	3

The sand is silty and has a high clay content. At the east end of the pit a pebbly, sandy clay shows at a depth of 3 or 4 feet, into which the sand appears to merge irregularly. Blue clay underlies the pit about 8 or 10 feet below the bottom. Sample *T-213* is a representative sample of the entire face taken at the west end of the pit. It has a fineness modulus of 1.75 and 53 per cent of the sand is retained on the 48-mesh screen. The color value of the organic matter is 50.

Cairo.—One mile west of Cairo, on the Thomasville-Cairo road, and on both sides of Little Tired Creek, a yellow to white, clayey sand, which is pebbly in places, occurs. This sand is somewhat similar to that at Parrish's mill, and has been used locally in Cairo.

Ocklocknee River.—Beautiful white sand, suitable for glass or building purposes, occurs in the bed of Ocklocknee River throughout its course across the southeast corner of the county. The sand is best seen at low water and is similar in character and in manner of occurrence to that further up the river in Thomas County (see p. 260). Fine-grained sand occurs on both sides of Ocklocknee River varying from 3 to 12 feet in thickness. Most of this is of poor quality, even for most building purposes, and its inaccessibility also eliminates it as a source of supply for some time to come.

Barnett Creek.—Along Barnett Creek, which forms the eastern boundary of the county, particularly near the Atlantic Coast Line Railroad crossing, east of Pine Park, a somewhat clayey sand occurs from 5 to 10 feet thick, covering an area of several hundred acres on both sides of the railroad. Further up the creek, smaller irregular deposits of sand of fair quality, also occur.

The Big Slough.—A large area of white, coarse, pebbly sand occurs in small dunes or hills, surrounding the Big Slough, a flat low area in the extreme northwest corner of the county. The sand contains about 12 per cent of clay and silt and considerable organic matter, and is of questionable value for building or glass purposes.

In addition to the localities mentioned, small deposits of clayey sand occur on terraces above many of the creeks, particularly Turkey, Big Tired, Black, and other creeks in the western half of the county.

HANCOCK COUNTY

No natural sand and gravel is produced in Hancock County. A few thin deposits of gravel are associated with the contact of the Lower Cretaceous and the crystalline rocks, and sand is found in the streams and in some of the Cretaceous beds.

Big Shoulderbone Creek.—Where the Eatonton-Sparta road crosses the creek it is about 25 feet wide below the mill-dam with granite boulders in it. It has excellent, coarse, clean, quartz sand in its bed and in bars along its course. The bar just below the dam has at least 50 carloads of good sand. Sample *T-110* is representative of the sand from this creek, and a mechanical analysis shows it to have a fineness modulus of 2.62 with 95 per cent coarser than the 48-mesh screen. The sand contains only a faint trace of organic matter. It is dark brown, contains about 10 per cent feldspar and some fine mica flakes. Grains of ilmenite and limonite are also common.

Little Shoulderbone Creek, 2½ miles further west, has sand similar to that in Big Shoulderbone, but in much smaller quantities, as the stream is only 6 or 7 feet wide. The sand bars are small, but the sand is of good quality and would supply the need for road and other local purposes.

Town Creek, in the southwest part of the county, is swampy and muddy below Allen Mill and is rocky with some sand above the mill. In the same part of the county small amounts of sand occur along Spring Creek, but Big Buffalo Creek, along its course in Hancock County, is too rocky to afford any but small quantities of sand. Little Buffalo Creek, a tributary of Big Buffalo Creek, at the point where the Sparta-Linton road crosses it, 4½ miles south of Sparta, has bars of from 10 to 50 cubic yards of coarse, brown sand, having 10 or 15 per cent feldspar and limonite, but well suited for concrete purposes.

Ogeechee River, which forms the eastern boundary of the county, has small deposits of sand in bars ranging from a few cubic yards to 50 cubic yards. The sand is gray or pale brown and usually coarse and well suited for concrete aggregate.

Carr's Station.—A cut in the Georgia Railroad at Carr's Station exposes from 5 to 15 feet of brown and red, somewhat clayey, sand overlying white clays and white clayey sand. Pebbly layers and coarse sand occur near the contact with the white clays.

Other deposits.—Hancock County uses on its roads a residual material, locally called gravel, produced from the weathering of crystalline rocks and consisting of angular fragments of chert and quartz in a clay matrix. The fragments range from half an inch up to several inches in diameter, and the material occurs in deposits from one to three feet thick. Pits have been opened in it on several of the roads leading out of Sparta, and also at Harris Mill. The material is fairly good for road purposes.

Just northwest of Linton, and within the town limits, on the Sparta road, from 2 to 3 feet of gravel composed of rounded quartz pebbles in a clay matrix, outcrops in a road cut for 200 feet. On the Sandersville road, one mile from Linton, clay gravel is exposed in several thin streaks in road cuts on the descent to Buffalo Creek. It is reported that it was found to a thickness of 5 feet in wells in this vicinity.

Powelton.—Just outside of Powelton, east of the Crawfordsville road, a hill 50 feet high is capped with good clay gravel, well suited for road material. Several streaks of gravel occur from 4 to 5 feet thick, and a small pit has been opened along the road. Other outcrops of gravel occur in the road further north.

HOUSTON COUNTY

In Houston County sand is produced for shipment on Mossy Creek, south of Tivola, and other smaller deposits of local value occur in a few other places in the county.

Perry.—On the Elko road, a half mile from Perry, south of Big Indian Creek, at Galilee Church, a deposit of grayish-yellow, fine-grained, silty sand occurs overlying red, residual, sandy clay. The deposit appears to parallel the creek with interruptions for some distance and is usually under 5 feet in thickness. About 5 acres of land in this vicinity are covered with the sand, and a small pit has been opened between the stream and the road. Sample *T-246* is typical of the deposit and possesses a fineness modulus of 0.69. Only 8 per cent of the sand is coarser than 48 mesh, showing it to be of little value for construction purposes. Similar sand in small quantities occurs on the National Highway, one mile west of the bridge over Big Indian Creek.

Mossy Creek.—One mile south of Tivola, on the Georgia Southern & Florida Railway, and about 6 miles from Perry, a commercial deposit of sand has been opened. The pit has been worked since prior to 1910 and covers a little less than 2 acres. The land is owned by O. M. Grady and T. J. Carling. Mr. J. Houser, of Tivola, operates the pit. Two types of sand are found, that in the upper part being pure white and that in the lower part yellow. The line of contact between the two sands is very sharp, but generally somewhat irregular.

Section at sand pit south of Tivola

	Feet
White, medium-grained sand	1–3
Yellow, coarse- to medium-grained sand	5–6

A sample (*T-247*) of the upper white sand has been analyzed, and the results indicate it to be suitable for the manufacture of bottle glass.

Analysis of white sand south of Tivola, T-247

Magnesia (MgO)	trace
Ferric oxide (Fe_2O_3)	0.65
Silica (SiO_2)	99.01

A mechanical analysis of this sand shows a fineness modulus of 1.93 and 75 per cent is retained on a 48-mesh screen. The organic color value is 200. Sample *T-248* is typical of the lower yellow sand, and its characteristics are similar to the white sand except the color. The sand is suited especially for brick and plaster mortar and may also be used for concrete. Apparently, at least 20 acres in this vicinity, north of Mossy Creek, are underlain by sand similar to that exposed in the pit.

Cooper property.—Mr. J. P. Cooper owns about 100 acres adjoining the Tivola pit, and approximately 15 acres of this are believed to be underlain by sand similar to that at the pit although the thickness is uncertain.

IRWIN COUNTY

Little sand of commercial value occurs in Irwin County near the towns, although local supplies may be had from stream branches or from local accumulations of sand at convenient points along the roads.

Allapaha River.—The sand-hill belt follows the east side of Allapaha River through the entire county, but only at the Atlanta, Birmingham & Atlantic Railway crossing, 10 miles southwest of Ocilla, and 8 miles northeast of Tifton, is there a possibility of commercial development at this time. The sand begins 500 feet east of the trestle and continues for 1,000 or more feet, having a thickness ranging from 10 to 20 feet. The deposit is very extensive and capable of immense production. The sand is white to pale yellow, medium- and fine-grained, and suitable for plaster or mortar work. The sand has been used in making the railroad fill across the river swamp. The following section is poorly exposed in the old workings:

Section on Atlanta, Birmingham & Atlantic Railway east of Allapaha River

	Feet
Soil and loamy sand	2
Fine-grained yellow sand	6–8
Fine-grained white sand	4–5

The quality is about the same as that along Seventeenmile Creek at Douglas (see *T-234*), and the extent of the deposit is very much greater than that along Little River in Tift County or further up Allapaha River at Rebecca. The sand belt continues southward to the county line but is not accessible to rail transportation.

The lower five feet at the pit described above is exposed to poor advantage and may be suitable for glass manufacture. The following analysis was made, but due to the fact that a clean sample could not be obtained, it is not an accurate representation of the sand.

Analysis of white sand on east side of Allapaha River, on Atlanta, Birmingham & Atlantic Railway

Magnesia (MgO)	trace
Ferric oxide (Fe_2O_3)	0.64
Silica (SiO_2)	99.21

JEFF DAVIS COUNTY

A large part of Jeff Davis County is covered with a thin veneer of fine-grained sand which is surrounded by clay at depths of from a few inches to several feet. No commercial deposits are worked in the county, and local supplies are generally obtained from accumulations in or along streams and ditches.

Fine-grained sand is particularly abundant east and north of the larger streams in the county, especially Hurricane and Whitehead creeks. Coarser sand, at least 3 feet thick, is in some places associated with the second terrace of Ocmulgee River. The largest deposit of this type occurs about two miles south of the Lumber City ferry.

Coarse sand, with some quartz gravel is found at different places in the county, generally along the divides. The thickness ranges from one to four feet, and greater depths are quite likely. None of these deposits appear to be of commercial value.

Immense quantities of medium- to coarse-grained sand occur in Ocmulgee River, which forms the northwest border of the county. Since this river is navigable, these deposits may be utilized later for commercial purposes or for construction work close to the river.

JEFFERSON COUNTY

The surface of Jefferson County is usually covered with a veneer of residual, gray or red clayey sand. No deposits of sand or gravel are commercially worked in the county, although small gravel deposits are known near Spread in the northern part of the county. Elsewhere, either sand or gravel deposits of any value are rare.

Louisville.—Small deposits, having a maximum thickness of 8 or 10 feet of faint yellow, rather fine-grained sand occur on the north side of Ogeechee River along the railroad and public road. This material is used locally. Sample *T-52,* representative of this sand, has a fineness modulus of 1.98 and 81 per cent retained on the 48-mesh sieve. The sand is composed mostly of sub-angular or angular quartz grains, and a few coarse grains of feldspar.

Sample *T-53* represents the red loamy residual sand so plentiful throughout the county and was obtained on the Wadley road, just east of the bridge over Ogeechee River. It contains about 10 per cent of clay, but otherwise its granulometric composition corresponds to sample *T-52.*

Along the Wadley road, at several points near Louisville, thin deposits, rarely exceeding two feet, of gravel in red sand and clay, are found. The pebbles are usually under one inch, and the material has been locally used in roads.

Stapleton property.—On the Savannah & Atlanta Railway, a quarter of a mile north of Stapleton station or one mile from Spread postoffice on the Warrenton road, from one to three feet of sandy gravel, consisting of granular quartz and limonite pebbles ranging from ½ to 1½ inches in size, occurs. The pebbles make up about 30 per cent of the whole. A small pit has been opened in the deposit, and the gravel was formerly used for railroad ballast and for local concrete aggregate. A railroad cut just north of the pit shows at least 3 or 4 feet of clay gravel, the upper part of which is sandy. Sandy gravel covers the surface of 4 or 5 acres close to the pit, but it is not likely that more than half of this area contains gravel even 2 or 3 feet thick. Sample *T-54,* taken from this deposit has a fineness modulus of 5.24 and 57 per cent is coarser than 4 mesh.

Rogers property.—On the Wrens-Spread road, half-way between the two places, about an acre of gravel occurs. The deposit does not exceed 3 feet in thickness, and the pebbles are of quartz and range up to 2½ inches in diameter. The Augusta Southern Railroad has bought part of the deposit, but it has never been developed. Smaller shows of gravel occur along this road, but none of them are of sufficient importance to even warrant a description.

Avera.—Just west of Avera on the Gibson road, near a church, and on the creek bank, from 4 to 5 feet of fine-grained sand occurs. The sand is of a very poor grade and suitable only for brick or plaster mortar.

JENKINS COUNTY

Surficial sands, light sandy clays, and clay cover Jenkins County and are underlain at depths of from 50 to 100 feet by strata of Alum Bluff age. No commercial sand pits are operated in the county, nor is there much possibility of opening commercial deposits. The surficial sand is generally thin and of little value except for local purposes.

Millen.—One mile south of Millen on the Garfield road, near the top of the slope to Ogeechee River, a small gravel pit has been opened for road purposes. The pit is mostly on the east side of the road and is about 50 by 100 feet. The gravel occurs in lenses from a few inches to a foot in thickness, in a red clay and sand mixture with a foot or two of sandy cover. Cross-bedding is very prominent, and the lenses vary laterally over short distances. The pebbles are of tough quartz, angular to sub-angular, and generally under an inch in diameter, although a coarser layer one foot thick is exposed on the floor of the pit. The pebbles coarser than 4 mesh make a fairly good road material. Situated as it is on a hill slope, further working will mean a greater cover to be removed, however, it seems that several acres can still be profitably worked. Tests of sample *T-48*, from the pit, show the fineness modulus to be 3.10, with 5 per cent of the dried material passing 100 mesh and 22 per cent coarser than 4 mesh.

Deposits of this character are likely to be found in the county along the Pleistocene terraces of Ogeechee River, which generally lie 25 to 30 feet above the stream. As a rule their extent and thickness will be small, and they will have a large percentage of clay.

JOHNSON COUNTY

Many deposits of thin gravel and considerable fine- and coarse-grained sand are found in Johnson County, although none is produced commercially. Dr. W. R. Flanders of Wrightsville has devoted considerable time prospecting for gravel in this county for the State Highway Commission, and it is to him that the writer is indebted for much data on the sand and gravel deposits in Johnson County.

A. GRAVEL PIT, W. A. FITZGERALD'S PROPERTY, 1½ MILES SOUTH OF OMAHA, OMAHA-FLORENCE ROAD, STEWART COUNTY

B. PIT OF KIRKPATRICK SAND & CEMENT COMPANY, 2 MILES WEST OF HOWARD, TAYLOR COUNTY

Wrightsville.—The local sand supply for Wrightsville is usually obtained from small deposits along Ohoopee River on the Dublin road. This sand is fine-grained, gray, and generally free from clay.

On the W. C. Brinson property, one mile south of Wrightsville on the Dublin road, several acres are underlain with a medium-grained, loamy sand said to be about 4 feet thick.

Kite.—A mile and a half north of Kite on the Wadley Southern Railroad, a cut 300 feet long exposes from 15 to 20 feet of fine- to medium-grained, clean, yellow and gray sand. An additional 700 feet of the cut shows from 3 to 7 feet of sand underlain by loamy sand and yellow clay. This sand is part of the sand belt which borders the east side of Little Ohoopee River for most of its course through the western part of the county. Sample *T-51,* from this deposit, shows a fineness modulus of 1.96 and 74 per cent coarser than 48 mesh. The sand is used by the railroad in its locomotives.

Cheaves property.—Five miles from Kite and one mile south of Gumlog Creek on the Wylie Cheaves property, is considerable sand and gravel. The largest deposit covers at least 3 acres about 800 feet west of the store and averages 4 or 5 feet in depth. A smaller deposit averaging less than 2 feet, lies just south of the store. About 2,000 feet southeast of the store is a deposit of 2 acres of fine-grained gravel averaging 2 to 3 feet in thickness. All of the gravel on this property would make excellent roads and if screened would serve as concrete aggregate.

Rowland property.—On the J. H. Rowland property, 5 miles from Wrightsville on the Kite road, and a quarter of a mile north of the road, is about 5 acres of thin gravel suitable for road surfacing from one to two feet thick underlain by clayey sand.

South of the Kite road and about 5 miles from Wrightsville, are two acres of gravel from 2 to 3 feet thick on the Burell Wombles property.

Small, thin deposits of gravel occur on the G. C. Raines, R. Sammons, Green Harrison, and S. F. Harrison properties located on or near the Gumlog and Kite roads from 5 to 8 miles from Wrightsville.

Donovan.—One mile east of Donovan and 3 miles northwest of Wrightsville on the R. E. Smith property, 20 acres of gravel occur averaging 1½ feet in depth and underlain by a coarse concrete sand.

On the Annison Poole property, half a mile from the station, are from 10 to 15 acres of sand gravel averaging 2 feet in thickness and suitable for local road or concrete construction work.

McCrary property.—On the M. G. McCrary property, 6 miles northeast of Wrightsville on the Bartow road, are 40 acres of excellent gravel ranging in depth from 2 to 6 feet. This deposit has been tested by Dr. Flanders of Wrightsville, and the average thickness for the 40 acres is about 3 feet.

On the Bartow road 3 miles from Wrightsville, T. J. Brantley has 4 acres of good sand gravel from 2 to 3 feet in depth.

Smith property.—On the J. W. Smith property, on the Wrightsville-Adrian road two miles from Adrian, are several hills capped with gravel. One of these, along the road, contains at least two acres of sand gravel from 1 to 2 feet deep and underlain by coarse sand; another hill 400 yards southeast of the first hill has a much larger acreage of excellent gravel from 3 to 4 feet deep and overlain by a few inches of sand. A very good coarse concrete sand has been deposited between the two hills mentioned above. In a well on the Smith place, 5 feet of coarse sand was struck overlain by 2 feet of gravel which was exposed at the surface.

On the J. M. Flanders property, 1½ miles from Adrian on the Wrightsville road, several small deposits of gravel averaging a foot in thickness occur. Half a mile from Adrian on this road, small deposits of gravel occur from 1 to 3 feet thick. On the Adrian road 11 miles from Wrightsville, 5 feet of clay gravel outcrop in the road cut just above Rose Branch. Considerable gravel is said to occur in the fields east of the road.

On the terraces along Ohoopee River sand and gravel from 1 to 2 feet occur for most of its course through the county.

Neels Creek.—Bordering both sides of Neels Creek on the Kite-Wrightsville road, a strip of clay gravel 300 yards wide and extending at least 200 yards to either side of the road up and down the stream, occurs. The gravel has been taken from a small pit at this point and has proved an excellent material for road surfacing.

Williams property.—On the C. L. Williams property 4 miles from Kite and within two miles of the Wadley Southern Railway, are four acres of white sand 6 feet in thickness and sufficiently pure to be used in the manufacture of bottle glass and the cheaper grades of window glass. An analysis of a sample of the sand sent by Mr. Williams from this deposit gave the following results:

Analysis of glass sand from C. L. Williams property, 4 miles from Kite; Sample T-272

Loss on ignition	.15
Lime (CaO)	.00
Magnesia (MgO)	.04
Alumina (Al_2O_3)	1.09
Ferric oxide (Fe_2O_3)	.24
Manganous oxide (MnO)	trace
Titanium dioxide (TiO_2)	.06
Silica (SiO_2)	98.45
Total	100.03

LAURENS COUNTY

Most of the southern part of Laurens County is covered with the mottled clays and sands of the Altamaha formation. Commercial sand is found in Oconee River at Dublin, and in banks opposite Dublin on the same river. Small deposits of gravel occur throughout the county.

Dublin.—East of Oconee River and about a mile from Dublin, an extensive area of sand occurs ranging in depth from 4 to 18 feet. The topography is rolling with ridges extending through the area. The Macon, Dublin & Savannah and the Wrightsville & Tennille railroads run through the deposit, and sand from about two acres along the former railroad has been removed and shipped to Macon and other points on the Macon, Dublin & Savannah Railroad, or used in the manufacture of artificial sandstone by the Georgia Cast Stone Company, whose plant is at the deposit, although not operating now. The sand is composed of medium-sized grains of clean quartz, generally pale yellow at the surface and becoming darker as one goes deeper into the sand. Toward the bottom of the cut the sand becomes coarser with some ¼-inch pebbles, finally grading into a reddish-brown argillaceous sand, about 2 feet thick, beneath which red clay occurs. Sample *T-11*, from the lower half of the deposit, shows a fineness modulus of 2.54, and an effective size of 0.283 mm. Over 18 per cent of the sand is coarser than 48 mesh. The coarser grains are rounded and sub-angular, and the color is orange yellow. The organic matter color value is 1,000.

The sand apparently occurs at a depth of from 5 to 15 feet over at least 100 acres in this vicinity. The deposit extends close to and south of the Wrightsville & Tennille Railroad for about a mile, where it widens out and occupies a large area extending back from the railroad on either side for over 1,200 feet. The Macon, Dublin & Savannah Railroad after branching off from the Wrightsville & Tennille Railroad passes through the main part of the sandy area for 1,000 feet and again about two miles southeast of Dublin it passes through the southeast extension of the same deposit for over half a mile. The best and thickest deposit is near the pit already opened along the Macon, Dublin & Savannah Railroad. The sand is leased by Leo P. Baum from Mr. Crafts, the owner, and is used in Dublin and in the construction of the concrete bridge across Oconee River at this point.

Oconee River.—A fine-grained flood-plain sand suitable for brick and plaster mortar occurs east of Oconee River, opposite Dublin, a few feet above the level of the river. This sand is used locally and is obtained from a small pit on land owned by Mrs. Brady, 500 feet east of the river and about the same distance above the bridge. The sand is handled by Leo Baum.

Excellent coarse-grained sand occurs in the bed of Oconee River and along the banks in the vicinity of Dublin and for practically the entire course of the stream through the county. This sand has never been used commercially to any extent but should the demand warrant it the location seems suitable for installing a centrifugal pump. Sample *T-13* was obtained from the river bank a few hundred feet north of the wagon road, opposite Dublin, and has a fineness modulus of 2.51 and 97 per cent is coarser than 48 mesh. The sand contains about 5 per cent feldspar, the balance being iron-stained quartz.

Other deposits.—Another extensive area of sand similar to that on the second terrace opposite Dublin is found on the Dublin-Wrightsville road near Brown's Chapel east of the river and 4 miles northeast of Dublin.

Smaller and more inaccessible deposits occur west of the river, on the second terrace near Cody Spring Church, and from Turkey Creek to the Wheeler County line. A somewhat more loamy sand occurs in a number of small areas on the north side of Ochwalkee and Alligator creeks in the southern part of the county. Much surficial sand occurs in southern Laurens County, usually less than 5 feet deep.

Considerable gravel, generally of small thickness but suitable for local road construction, occurs throughout the county.

Carter property.—On the Dr. J. G. Carter and Warren Carter properties along the Central of Georgia Railway and Dixie-Overland Highway, one mile west of Scott, an average of 2½ feet of sand-gravel with coarse sand beneath, occurs. Over 100 test holes dug under the direction of Dr. W. R. Flanders of Wrightsville encountered from 2 to 5 feet of gravel. In this vicinity it is believed that 3,000 acres are underlain by gravel.

Elsewhere in the county, thin but extensive deposits of clayey ferruginous gravel have been noted along the Mt. Olive road and Strawberry Branch, 4 miles northwest of Dublin, near Excelsior School. Gravel also occurs along the Hawkinsville-Blackshear Ferry road, near the Industrial School, 7 miles northwest of Dublin. In the southern part of the county small scattered areas of thin gravel occur due to the weathering of a conglomeratic phase in the Alum Bluff formation.

LEE COUNTY

No sand of commercial value was noted in Lee County, and very little sand suitable even for unimportant local work was found except along Kinchafoonee and Muckalee creeks. Thin gravel deposits sometimes are found near the tops of divides.

Muckalee Creek.—Four miles directly east of Leesburg, on the Philema road, a small flood-plain deposit of medium-grained, fairly-good, yellow sand, ranging from 6 inches to 2 feet in depth, occurs. In the road 500 feet west of the creek, 5 feet of a loamy sand suitable for brick mortar may be seen. The Georgia, Southwestern & Gulf Railroad runs through this locality, and it is possible that larger deposits can be found along it.

Kinchafoonee Creek.—Kinchafoonee Creek is about 80 feet wide, rather swift, and with intermittent bars of coarse sand along its course. One and a half miles west of Leesburg, west of Kinchafoonee Creek at Jackson Bridge, a fine-grained, silty sand occurs that is hauled to Leesburg for local use. About 700 feet below the bridge on the inside of a sharp curve in the river a somewhat better and coarser sand has been deposited by the creek during high water. Sample *T-222* is representative of this sand and has a fineness modulus of 1.40 and 41 per cent coarser than 48 mesh. It contains a trace of organic matter. The sand is pale buff and composed mostly of angular, iron-stained quartz and some fine ilmenite grains.

At places along the stream bank a coarse sand suitable for concrete and underlying the surficial sand from 4 to 7 feet, may be seen. This sand usually lies directly upon the Ocala limestone or upon a blue clay into which it may blend. None of this sand, however, exceeds 10 feet in thickness at the maximum, and most of it is of very poor quality and the deposit spotty.

On the Smithville-Dawson road, one mile east of Kinchafoonee Creek, loamy sand occurs in the road cut, giving place at a depth of from 1 to 2 feet to medium- to coarse-grained, somewhat clayey, yellow sand. The thickness is probably less than four feet. The sand occurs mostly east of the creek where a small pit has been opened from which sand was used in the construction of the bridge. The sand here is medium-grained and of fairly good quality and about 4 or 5 feet thick. A deposit of white, fine-grained sand occurs along the creek just above the level of the stream channel.

Other deposits.—The county is sandy for a mile or two south of Smithville, but no deposits of value were seen, although local accumulation, particularly near the higher elevations, may be valuable for road building.

In a cut on the Leesburg-Albany road, 1.9 miles south of Leesburg, 150 to 200 feet of sandy, red, clay gravel, containing 50 per cent of sub-angular quartz and ferruginous sandstone pebbles was noted. The gravel is a small lens showing an irregular thickness of from two to four feet and is of poor quality and probably of very limited extent. The deposit is at a comparatively high elevation and seems to be a remnant of a more extensive deposit.

LIBERTY COUNTY

The usual gray or yellow surficial sands, peculiar to the eastern part of the state, and underlain by clays and sands at differing depths, cover most of Liberty County. There is no commercial production of either sand or gravel in the county, although sand pits were formerly operated on the Atlantic Coast Line Railroad, east of Altamaha River, opposite Doctortown, and gravel was mined on a small scale on the same railroad near Fleming.

Altamaha River.—The sand-hill belt extending east of Altamaha River, intermittently through Liberty County, is commercially accessible along the Atlantic Coast Line Railroad about 5 miles west of Ludowici. An old pit was operated by this railroad for locomotive sand prior to 1914. The pit covers 8 or 10 acres north of the track, and the face is 900 feet long, extending north and south, and from 6 to 18 feet in height, averaging 10 feet. The sand is similar to that obtained east of Everett City, on the same side of the river, and is fine-grained, yellowish, and clean, without signs of stratifications. Sample *T-32* is representative of the sand near this place. It has a fineness modulus of 1.72 and 66 per cent coarser than 48 mesh. The organic content is insignificant. The grains are almost entirely of faintly-stained quartz.

Much sand remains along the railroad west and north of the pit and also south of the railroad and for a considerable distance up and down the river on either side of the railroad.

Fleming.—Four miles southwest of Fleming on the Atlantic Coast Line Railroad a small deposit of clayey gravel made up of quartz pebbles occurs. The deposit is on the Phillips' place, 800 yards south of the railroad, and has been prospected to some extent. A spur was put in from the railroad, a distance of a few hundred feet, and a few carloads were shipped prior to 1900. The test pits show gravel to a depth of 5 feet. An excavation 700 feet long, 30 feet wide and 5 feet deep shows the following section:

Section at old gravel pit 4 miles southwest of Fleming

	Feet
Fine, quartz gravel, pebbles ¼ to ¾ inches	1
Sandy clay	1½
Medium-sized sandy gravel, pebbles ¼ to 1 inch	3

Sample *T-36* is representative of the gravel and shows a fineness modulus of 5.00 and 57 per cent retained on the 4-mesh sieve. It would make an excellent roofing gravel. The area underlain by the deposit is probably less than 4 acres. The rather poor quality of the material for use in road building or in concrete work, together with its limited extent and thickness makes the deposit of little commercial value.

Flemington.—Gravel similar to that in the old pit south of Fleming shows at the cross-roads at Flemington and also on the road half a mile north of Flemington, but its extent is small and the gravel is of little value.

LOWNDES COUNTY

Sand or sandy clay covers most of Lowndes County and is underlain by blue and yellow clays and sands of Alum Bluff age and at greater depths by the massively bedded Chattahoochee limestone. No sand deposits are worked commercially in the county, and although much of the surface is sandy, deposits of good sand for even local use are scarce.

Withlacoochee River.—Sand from Withlacoochee River has been used in the construction of the concrete bridge on the Quitman-Valdosta road near Blue Springs and is of fairly good quality. It is rather superficial, though, and is restricted to bars in the river channel or to patches along and near the channel. Sample *T-241* is from the deposit along the river at this point. It has a fineness modulus of 1.67 and 53 per cent is retained on the 48-mesh sieve. The color value of the organic matter is 100. The grains are mostly of quartz and a few of sandstone.

East of the river, along this road, an irregularly stratified deposit of yellow, clayey sand, occurs, probably under 10 feet in thickness. A similar sand has been deposited along the river on the upper Quitman road, in a strip 300 feet wide and from 8 to 12 feet in depth. The sand is suitable for brick mortar and plaster, but is not so desirable for concrete. On this same road, between the two channels that make up the river at that point, a coarser, white sand occurs, of much better quality but more difficult to get than that east of the bridge. In places this sand is pure enough for the manufacture of glass.

MACON COUNTY

No sand is being produced for commercial shipment in Macon County, although Flint River has large deposits both in the bed of the stream and along the banks.

Montezuma.—A bar in Flint River just above the mouth of Spring Creek, east of the river, owned by Mack De Vaughn, produces sand for local consumption. Sample *T-250* shows the sand to be of good quality for use as part of the concrete aggregate. The fineness modulus is 2.50 and 82 per cent of the sand is coarser than the 48 mesh screen. It is yellowish-gray and composed mostly of quartz, although the coarser grains (on 4 mesh) contain about 20 per cent of feldspar. The organic color value is 80.

On the upper road from Montezuma to Oglethorpe, one mile from Montezuma, a small pit has been opened for local supply in a fine-grained, buff-colored sand deposit occupying a small hill just above the river swamp. The sand is suitable for brick and plaster mortar, but it will not make the best concrete due to its fineness and silt content.

Excavations for the new bridge across Flint River at Montezuma exposed excellent medium- to coarse-grained sand on the east side at the swamp level. This sand has been used in some of the concrete construction in connection with the bridge. Deposits so situated, however, are of small value, since with every rise in the river they are covered with water.

Lewis Mill.—One mile south of Montezuma, on the Cordele road, the following section was noted:

Section at Lewis Mill, one mile south of Montezuma

	Feet
Sandy soil and sand	2–4
Red and yellow, coarse, clayey, gravelly sand	4
Red, fine-grained, clay and sand gravel	6
White, fine-grained sand and clay	3

McINTOSH COUNTY

Most of McIntosh County is flat and sandy with a ridge of sand hills paralleling Altamaha River on the east. Terrace sands and clays of Pleistocene age cover the surface of the county and are underlain by sands, clays, marls, and limestones of the older formations. Sand is being dug along the Seaboard Air Line Railway north of Altamaha River.

Altamaha River.—A very prominent ridge of sand hills roughly parallels the northeast side of Altamaha River along the western half of its course along the southern border of McIntosh County. These sand hills reach a height of 60 feet above the river bed in some places and have an enormous quantity of sand. The sand is usually fine-grained, but clean, and suitable for brick mortar and plaster, and it has also been extensively used in concrete.

Altamaha Supply Company.—A large area of the sandy ridge near the Seaboard Air Line Railway between Everett City and Barrington is owned by the Altamaha Supply Company, of which Mr. R. R. Hopkins, of Brunswick, is president. The pit on this property is located three-quarters of a mile east of the Seaboard Air Line Railway trestle and 4½ miles southeast of Everett City. (Plate X-B.) The face of the pit is 500 feet long and from 5 to 25 feet high, averaging about 15 feet. The pit covers about 10 acres. The sand becomes yellow to pale yellow with depth, although the upper 3 or 4 inches has been leached pure white by the action of rain and organic acids. The sand appears to be quite uniform throughout its thickness, although a slight increase in the size of the grain and an increase in purity is noted toward he bottom of the pit. A Marion steam shovel having a 60-foot boom and a 1¾-yard dipper is used in loading the sand on the cars. The production ranges from 3 to 10 cars daily. Sample *T-31*, from this pit, has a fineness modulus of 1.76 and 69 per cent coarser than 48 mesh. The organic color value is 200.

The pit has been in operation since 1911 and during that time a great deal of sand has been shipped for use in the construction of the acid plant near Brunswick and for the construction of a number of buildings in Jacksonville, Brunswick, River Junction, and other points.

The surficial sand so prevalent throughout the county is in places pure enough for use in glass-making. The thickness of this sand, however, is frequently limited to the upper 2 to 5 feet, but it is likely that deposits close to railroads may be discovered of sufficient thickness to warrant commercial exploitation.

Crescent.—On the bluffs overlooking Sapelo River, half a mile east of Crescent, white sand two feet thick occurs, overlying eight to fifteen feet of brown, clayey sand. An analysis of the white sand gave the following results:

Analysis of surficial sand near Crescent, T-33

Moisture at 100° C	0.00
Loss on ignition	0.13
Soda (Na_2O)	0.23
Potash (K_2O)	0.61
Lime (CaO)	0.00
Magnesia (MgO)	0.07
Alumina (Al_2O_3)	1.36
Ferric oxide (Fe_2O_3)	0.55
Titanium dioxide (TiO_2)	0.19
Silica (SiO_2)	96.74

White sand of similar character occurs in extensive deposits of unknown depth along the old Georgia Coast & Piedmont Railroad between Ludowici and Darien Junction.

MARION COUNTY

Large quantities of fine-grained sand are found in northern Marion County within a mile or so of the Atlanta, Birmingham & Atlantic Railway. Just over the line in Taylor County the sand is commercially exploited in large pits. This deposit which forms part of the Fall Line sand-hill belt, continues westward across the entire county, although at no other point are transportation facilities so close.

In the southern part of the county the streams usually have sand in sufficient amounts for local purposes. This is especially true of Richland, Buck, and Allonahatchee creeks. Along the smaller branches at most road intersections from 5 to 100 cubic yards of coarse sand occur, suitable for concrete work, which has been deposited during flood periods. Such deposits usually afford local supplies to the towns in the county. Almost everywhere throughout the county thin surficial deposits of fine-grained, somewhat loamy sand can be found which are used in constructing the sand-clay roads.

Gullies and road cuts in the central part of the county, particularly near Buena Vista, expose great thicknesses of hard, white, rather fine-grained sand of the Providence member of the Ripley formation, or coarser, yellow sand of the Cusseta member. During heavy rains great quantities of sand are washed from the gullies and collect as sand streams along branch bottoms or hollows. A particularly prominent sand stream occurs about a mile north of Tazewell. (Plate XI-A.)

MILLER COUNTY

The surface of Miller County, like that of the surrounding counties, is practically flat to slightly rolling. The Ocala limestone underlies the entire county, but is represented at the surface by flint boulders and residual clays and sand, and has a thin veneer of gray surficial sand on top. No commercial sand or gravel deposits are worked or known in the county. Small deposits of fine-grained, loamy sand occur in the bed of Spring Creek and in some of its tributaries and in small deposits in places along the banks, but the quality is very poor and the amount usually small.

MITCHELL COUNTY

Sand covers most of Mitchell County, although clay and sandy clay are common and frequently come close to the surface in sandy parts. Sand deposits occur along Flint River, particularly opposite

Newton, and as scattered local remnants of former fluviatile deposits. A few deposits of gravel suitable for road building occur near the tops of the higher portions of the county.

Camilla.—Sand for local use in Camilla is hauled from a pit on the Camilla-Newton road, opposite the cemetery, 1 mile west of Camilla. The worked-over parts cover about 2 acres and show fine- and medium-grained sand about 5 feet thick and underlain by yellow clay. The distribution of the sand both as to quality and quantity is very irregular, although the sandy area extends for several hundred yards along the road and back from it.

Flint River.—A prominent and extensive deposit of fine and medium-grained, yellowish sand occurs 1,000 feet east of Flint River at the ferry, just opposite Newton. The sand occupies a long ridge and is 10 to 30 feet thick, the average thickness being at least 20 feet for a width of 500 feet. The ridge is said to extend north about two miles and to the south about half a mile from the Newton Ferry road. The deposit at this point is located mostly on the Lee Hill plantation. Intermittent ridges of this type extend east of the river for most of its course through the county. The sand is similar to that at East Albany, to the north. Tests have been made on sample *T-220,* which show it to have a fineness modulus of 1.63 and 59 per cent coarser than the 48-mesh screen. The organic content has a color value of 175. The grains are of faintly iron-stained quartz.

Although deposits of this kind along this part of Flint River are inaccessible to railroads at present, it is possible that the sand could be shipped down the river in barges. The bed of Flint River itself should afford an unlimited supply of coarse sand for construction purposes on work located near it.

Cowart and Hand properties.—Dark-red gravel occurs in a narrow ridge extending east and west and is exposed where the Pelham-Camilla road cuts the ridge, 7.6 miles south of Camilla, for a distance of 150 feet, and to a maximum thickness of 4 feet on the A. B. Cowart and J. L. Hand properties. The matrix is clay and contains from 25 to 40 per cent quartz pebbles from a half to two inches in diamter. The gravel is a lens sloping to the south about 15 degrees and coming to the surface where it can be traced for 600 feet to the east of the road and about 400 feet to the west. Not more than 4 or 5 acres are covered with the gravel in this vicinity, although a larger area may be underlain with it at a depth of from 1 to 3 feet, particularly to the east and west, along the ridge.

Samples tested in the State Highway Laboratory of the Georgia School of Technology are recorded below:

Tests of road gravel from Mitchell County

Sample	Percentage retained on following mesh sizes:										Clay	Organic test
	2	4	10	20	30	40	50	80	100	200		
1	24.1	36.1	43.6	56.5	73.1	82.0	85.8	90.5	91.5	97.0	34	Clear straw color
2	35.8	49.3	59.5	69.1	75.8	79.1	81.8	85.4	86.2	96.0	19	Clear straw color
3	17.6	36.8	54.1	62.3	65.9	70.7	78.0	85.6	88.1	97.0	18	Black

1 and 2.—Taken 100 feet east of road cut on J. L. Hand property.
3.—Taken from Wilbur Tucker property.

Wilbur Tucker property.—A small, thin deposit of sandy gravel, about an acre in extent, occurs 2 miles north of Pelham between the Dixie Highway and the Camilla-Cotton road. The actual thickness and extent of the gravel could not be determined, although it is questionable whether it is of sufficient size to be used even for local road purposes.

MONTGOMERY COUNTY

Large quantities of good sand occur in Oconee River and this sand has been used in concrete bridge construction over the river west of Mt. Vernon. A sample tested by the State Highway Department showed its tensile strength to be 171 and 148 per cent of Ottawa sand at 7 and 28 days, respectively, and a mechanical analysis gave the following results:

Mechanical analysis of sand from Oconee River, at Mt. Vernon bridge

	Per cent retained on following mesh sizes:								
Meshes	4	10	20	30	40	50	80	100	200
Percentages	12.1	32.1	51.4	64.8	76.7	89.2	96.2	96.6	99.6

Elsewhere in the county small, thin deposits of sand and gravel occur, the latter usually on the tops of the hills. Altamaha River below the crossing of the Georgia & Florida Railway has large quantities of excellent sand, and should the demand warrant, a good site for the installation of a pump is offered here.

MUSCOGEE COUNTY

Commercial sand and gravel is produced in Muscogee County from the deposits along Bull Creek. Numerous deposits of clay gravel near Columbus furnish excellent road material for the county.

Flournoy et al. property.—The J. F. Flournoy property comprises about 14 acres along Bull Creek just below the Seaboard Air Line Railway bridge. J. M. Rutledge and G. W. Chestnut of Columbus have built a screening plant and drag-line system along the creek on this property and pay a royalty for the sand and gravel removed. (Plate XI-B.) A ½-yard drag bucket with ½-inch steel cable is used, and the sand dragged to the top of a 20-foot tower over a wooden incline and passed through a ½-inch revolving trommel. A 25-horsepower hoisting engine is used. An excellent coarse-grained concrete sand is obtained which is delivered for use throughout Columbus and is also used in the county road paving operations. The excavation from which the sand is scooped shows up to 8 feet of a mixture of sand and gravel, the gravel composing 25 per cent. Thicknesses of from 15 to 20 feet of sand and gravel have been encountered on this property. The sand is recovered over a distance of 450 feet. (Plate XII-A.) Formerly an elaborate washing and screening plant was operated by the Columbus Sand and Concrete Company on the Flournoy property 200 yards below the Seaboard Railway crossing, but it has since been abandoned.

Morris property.—Mr. W. M. Morris owns land along Bull Creek, a half mile northeast from the Buena Vista road. In this distance sand and gravel have collected in large quantities in bars along the creek. The entire creek bed has an excellent clean quartz gravel which forms deposits up to 14 or 15 feet thick and 300 to 400 feet wide. In places vegetation has grown up on these bars, and the gravel is not at once apparent. The pebbles range from ¼ inch to 3 inches in diameter and consist of tough, vari-colored quartz generally rounded or sub-angular. The deposits have been left by the creek in flood times and naturally decrease in coarseness the further they are located from the main channel.

It is possible to obtain three grades of material from the creek (1) gravel, which has about 40 per cent sand; (2) concrete sand, ranging in size from fine grains to ¼ inch; (3) fine-grained, clean, white sand used for brick and plaster mortar, which occurs on the stream bank or at the outer edge of a bar away from the stream. The sand and gravel is loaded on wagons or trucks by hand labor and then passed through a quarter-inch screen into a bin which empties, when full, into a railroad car below. Sample *T-92*, taken from the Morris property, but typical of Bull Creek sand, has a fineness modulus of 2.85 and 90 per cent coarser than 48 mesh. The organic color value is 50.

Analysis of sand from Morris property along Bull Creek, T-92

Ferric oxide (Fe_2O_3)	3.21
Silica (SiO_2)	95.84

The bank of the first stream terrace just above the bed of the stream and usually from 100 to 400 feet back from the stream shows a cover of clay and sand from 5 to 10 feet thick, beneath which from 2 to 5 feet of very high-grade gravel shows.

Muscogee County gravel pit.—North of the St. Marys road, 3½ miles from Columbus, Muscogee County has operated a road-gravel pit on its 102-acre farm since 1915. The gravel is mined with a 60-horsepower Thew No. 0 gasolene shovel using a ¾-yard bucket and is loaded directly into auto trucks. (Plate II-B.) The face of the pit is about 14 feet high and 500 feet long. The gravel has a fairly large amount of clay and sand which causes it to cement so well as to be mined with difficulty even with the steam shovel. A general section at the pit is given:

Section at Muscogee County gravel pit, St. Marys road, 3½ miles from Columbus

	Feet
Red, sandy clay soil	1–2
Clay gravel, rounded and sub-angular pebbles, highly cemented	8
Coarse, clayey sand with a few pebbles	1
Reddish clayey sand, pebbles scant	3–4
Clay gravel with fewer pebbles than upper layers	2–3

Sample *T-90*, representing the face of the pit, shows a fineness modulus of 6.07, and 75 per cent coarser than 4 mesh. The clay content is 6 per cent.

At the southeast end of the pit the sand layer is from 5 to 7 feet thick. (Plate XII-B.) A well 25 feet back from the face, and above it, shows 22 feet of gravel, sand, and clay similar to that in the section. In the immediate vicinity at least 3 acres are underlain with gravel. A few hundred yards west of the present pit, a small pit was opened some years ago, but the clay content of the gravel was found to be too large. The gravel north of the pit is believed to thin out and contain more clay than that now worked.

On the land of A. L. Barnes, adjoining the county land to the east, a maximum thickness of 4 feet of similar, although more sandy gravel, outcrops in the road cut.

Fort Benning gravel pit.—About 5 miles from Columbus on the Cusseta road near the top of Torch Hill, on the Fort Benning Reservation, a pit has been opened to supply gravel for road building in the reservation. A section of the deposit shown in the pit is given.

Section at pit on Torch Hill

	Feet
Red, coarse, clayey sand	2–8
Granular rounded quartz gravel with bright red clay matrix	6
Coarse, red, clayey sand	1–2
Quartz gravel with red clay	4

Central of Georgia Railway.—A hill of clay gravel extends eastward along the north side of the Central of Georgia Railway yards, from a point 700 feet east of the Muscogee Guano Company, for 1,000 feet. Cuts show from 2 to 8 feet of sandy, clayey gravel with little or no cover. The pebbles range from 1 to 5 inches in diameter. Good road gravel appears to underlie about 5 acres. At the eastern end of the hill Muscogee County formerly worked the gravel for road material.

West of Midway Street a hill of sandy gravel, ranging from 2 to 6 feet thick, occurs.

Columbus-Talbotton road.—Where the Talbotton road crosses Randall Creek, considerable quantities of coarse sand suitable for local uses are found in the stream bed. At Bull Creek, near this road, very little gravel was seen in the stream bed as it appeared to be composed of solid granite-gneiss for some distance.

Bank gravel in fairly thick lenses occurs in Cretaceous strata along this road from the 9-mile post to within 3 miles of Columbus. Between

A. WORKING FACE SHOWING WAVY STRATA, J. W. DILLON PIT, WILLIAMS STATION, THOMAS COUNTY

B. WHITE SAND BAR ON OCKLOCKNEE RIVER JUST ABOVE THE THOMASVILLE-ALBANY ROAD, THOMAS COUNTY

5¼ and 5½ miles of Columbus, 5 feet of gravel is exposed in a sandy clay matrix. The pebble proportion is smaller than is usual in such deposits, and it does not appear to be very extensive, as the outcrop extends only 200 feet along the road. Gravel also occurs in road cuts in small quantities, 4½ miles from Columbus, but is of value only for road material. A cut 20 feet high, 3½ miles from the city, shows several layers of sandy clay gravel. Cuts along the road 2½ miles from Columbus, although in a built-up section, show up to 10 feet of clay gravel for 500 feet. Wells on the hills above did not appear to encounter much gravel.

Buena Vista road.—A ditch along the Buena Vista road, 4½ miles from Columbus, shows a maximum of 5 feet of coarse, well-cemented, clayey sand gravel. The pebbles range up to 3 inches, the largest being near the base of the deposit. The extent of the gravel appears to be variable and erratic.

Four miles from Columbus, 2 feet of medium-pebbled gravel shows in a road cut in short variable lenses in clay. The gravel occurs in several thin layers from a few inches to a foot thick. About 5 miles from Columbus 1 foot of gravel shows in the road cut, but further back from the road and capping some of the hills, the gravel appears to be thicker, although the pebbles are usually small. Similar gravel 6 miles from Columbus shows in several road cuts.

River road.—At several cuts on the River road, gravel outcrops from 1 to 2 feet thick. Just east of the reservoir and near this road, the gravel is from 1 to 4 feet thick and consists of quartz pebbles 1 to 2 inches in size, making up 60 per cent of the mass and embedded in clay.

Jordan property.—A small pit has been opened along the River road on the G. Jordan property, north of Columbus. The material was used for concrete aggregate and in road construction. The pit shows about 7 feet of red clay gravel becoming lighter in color near the bottom and which cements well. Above the gravel, and grading into it laterally, from 3 to 10 feet of coarse, red, clayey sand occurs. The pebbles are coarse, ranging up to 4 inches in diameter and averaging from 2 to 3 inches. In the road cut north of the pit, the pebbles make up 80 per cent of the mass.

Wynn property.—East of the road and opposite the Jordan pit, considerable gravel covers some of the fields on the T. J. Wynn farm.

A well 800 feet northeast of the road cut was reported to have encountered the following section:

Section of well on T. J. Wynn property

	Feet
Clayey sand and clay	6–8
Red clayey gravel	10
Clayey sand with gravelly layers	7
Red, plastic clay	2

On a hill on the W. D. Jones property, east of the road, 15 acres are said to be covered or underlain with gravel, although the thickness could not be determined.

Upatoi Creek.—Like Bull Creek, Upatoi Creek has immense quantities of sand and gravel in bars along its course. At the Seaboard Air Line Railway crossing the deposits are particularly prominent. Excellent quartz gravel lies in the stream bed, and along the stream banks sand is mixed with the gravel, making a natural concrete aggregate. A finer-grained sand, suitable for brick and plaster mortar, lies a few feet above the coarser sand and gravel, on the banks, or on islands. The gravel bars near the bridge are almost 500 feet long and 150 feet wide, one lying on either side of the crossing. The thickness of the gravel ranges from 2 to 8 feet.

Bars similar to this, although not so large, occur for some distance below this railroad crossing and also extend up-stream to a point above the Central of Georgia Railway crossing, 1 mile above the Seaboard Air Line, where they are also very prominent. The gravel extends much further up, although in smaller quantities than at the railroad bridges, but it is doubtful whether it goes much beyond the Buena Vista road. Sample *T-93,* typical of the Upatoi Creek gravel and obtained at the Seaboard Air Line Railway crossing, showed a fineness modulus of 3.11 and 8.9 per cent retained on the 4-mesh screen.

Sand Hill.—At Sand Hill Station on the Central of Georgia Railway, 7½ miles from Columbus on the Cusseta road, a hill 50 to 60 feet high is covered with fine- to coarse-grained sand of uncertain thickness. A quarter of a mile northeast of this hill where the railroad crosses Tiger Creek, north of the creek a section shows considerable sand, representing a former deposit of this stream and Upatoi Creek.

Section at Tiger Creek, Central of Georgia Railway crossing

	Feet
Gray to yellow clay	3–4
Coarse, clean, white sand	6
Pebbly, somewhat clayey, yellow sand	7
Clayey and fine-grained silty sand	4
Coarse, white sand	3

Further up-stream more of the finer-grained sand is shown in the section. The top of the sand is on a level with the railroad grade, and the land slopes downward to the creek east of the railroad.

Through the western part of Muscogee County a continuation of the Fall Line sand-hill belt passes, and the fine-grained sand ranges from 5 to 15 feet in thickness, but no means of transportation are near.

PIERCE COUNTY

Large deposits of sand are found in Pierce County along Satilla River and the larger creeks. A pit is in operation just north of the river on the Atlantic Coast Line Railroad.

Atlantic Coast Line Railroad.—Sand, forming part of the extensive deposit lying north of Satilla River, is being mined by the Atlantic Coast Line Railroad largely for use in locomotives. The pit is west of the railroad, a quarter mile north of Satilla River bridge, where about 8 acres of sand have been removed. The face, which parallels the railroad, is 800 feet long and from 5 to 15 feet high, although the average is about 11 feet. The sand is yellow near the surface but becomes paler in the lower half of the deposit. It is made up of sharp, iron-stained grains of quartz. No signs of stratification were noted in the deposit, and its present position appears to be due entirely to wind action. Practically no clay or organic matters occurs in the sand. The deposit is worked by colored hand labor, the sand being shoveled into wheelbarrows which are unloaded in the cars. Sample *T-27*, representative of the sand from this pit, has a fineness modulus of 1.67 and 62 per cent is coarser than 48 mesh.

Analysis of sand from pit on Atlantic Coast Line Railroad, 3 miles northeast of Waycross

Loss on ignition	0.08
Ferric oxide (Fe_2O_3)	0.51
Titanium dioxide (TiO_2)	0.09
Silica (SiO_2)	98.74
Undetermined	0.58
Total	100.00

Sand of this type occurs almost continuously along the north side of Satilla River. Its surface is undulating or even hilly, and thicknesses of from 20 to 40 feet are said to have been encountered in wells dug in the sand belt.

On the western edge of the county, north of the Atlanta, Birmingham & Atlantic Railway crossing of Satilla River, is an abandoned pit, from which, prior to 1910, some sand was shipped mostly for locomotive purposes by this railroad. The cut is about 1,000 feet long and 125 feet wide and the sand is of the usual color and texture characteristic of such deposits. The deepest part of the cut shows at least 15 feet of sand without indications of stratification. A very large deposit is here easily accessible to transportation. Sample *T-29*, from this deposit, has a fineness modulus of 1.59, and 60 per cent is retained on the 48-mesh sieve.

Hurricane Creek.—Continuous sand belts lie north and east of both Hurricane and Little Hurricane creeks for their entire course in the county. The only point at which they can be commercially developed is at the Atlantic Coast Line Railroad crossing of Hurricane Creek, 1½ miles north of Blackshear. The deposit here is from 1,000 to 1,500 feet wide and from 10 to 40 feet thick. A section at the thickest part of the deposit near the north abutment of the railroad bridge was noted.

Section of sand deposit on Hurricane Creek, 1½ miles north of Blackshear

	Feet
White, leached sand with some vegetable matter	1
Fine-grained, yellow quartz sand	15
Coarser and paler sand with some grains up to $\frac{3}{16}$ inch	10
White, medium-grained sand suitable for glass	6–8
Yellow, clayey sand	4

No signs of stratification were seen in the section and the yellow sand above merges gradually into the white sand below. Streaks of stained sand occur irregularly through the white material and detract from its value for glass-making.

A section 800 feet north of the first section showed similar white sand.

Section 800 feet north of railroad bridge abutment, 1½ miles north of Blackshear

	Feet
Yellow, fine-grained sand	4
Clean, white sand	2
White sand with more impurities than that above	3-5
Yellow, clayey sand	1

Analyses were made of the natural white sand from this section and also of the same sand after the clay had been washed out.

Analyses of sand from east side of Hurricane Creek, at Atlantic Coast Line Railroad, 1 mile west of Blackshear

Constituents	Washed	Unwashed
Moisture at 100° C	0.00	0.57
Loss on ignition	0.04	0.76
Lime (CaO)	0.00	0.00
Magnesia (MgO)	trace	0.03
Alumina (Al_2O_3)	0.05	1.16
Ferric oxide (Fe_2O_3)	0.31	2.11
Titanium dioxide (TiO_2)	0.04	0.27
Silica (SiO_2)	99.49	95.20

On the Patterson-Blackshear road, north of Hurricane Creek, yellow, fine-grained sand from 10 to 20 feet thick occurs, but no white sand is uncovered.

PULASKI COUNTY

In the southern part of Pulaski County, surficial gray sands are common, but usually of small thickness. No sand is produced commercially in Pulaski County, although Ocmulgee River, both in bars along its course and in deposits on its banks, affords abundant supplies. Elsewhere in the county, sand is rather limited.

L. E. Jordan property.—A fine-grained, white sand is said to occur along Ocmulgee River, 1½ miles above Hawkinsville. When visited by the writer the deposit was under water due to heavy floods.

About a mile below Hawkinsville, west of the river, a deposit of fine-grained, silty sand occurs suitable for brick and plaster mortar, but hardly desirable for important concrete construction.

The numerous bars of excellent sand in the bed of Ocmulgee River, which flows through the county, will furnish plenty of sand should the demand warrant the installation of a pump near the railroad crossings at Hawkinsville.

QUITMAN COUNTY

Deposits of gravel occur on the second terrace overlooking Chattahoochee River near Georgetown, but none is produced in Quitman County except for local purposes.

Central of Georgia Railway pit.—Prior to 1910 considerable gravel for ballast purposes was shipped from a pit along the Central of Georgia Railway, about 1½ miles southeast of Georgetown. None is being shipped now, although some still remains near the railroad with a rather thick cover in places. The pit covers several acres and is located on three sides of the hill in which the gravel occurs. When the pit was opened, the cover was thin, but as it was worked back toward the center of the hill the clay overburden became too thick to warrant the expense of further removal.

Section at Central of Georgia Railway pit, Georgetown, north side of pit

	Feet
Red, sandy, pebbly clay	8–12
(Further back in hill this reaches 20 feet in thickness.)	
Fine, clay gravel, pebbles up to 1 inch in size	5
Fine, sandy gravel, pebbles up to 1 inch in size	2
Coarse, clay gravel, pebbles up to 3 inches in size	1–2
Red, mottled, sandy clay	4

Sample *T-223*, representative of the entire thickness of gravel, showed a fineness modulus of 6.29 with 80 per cent of the pebbles coarser than 4-mesh. The pebbles are composed mostly of tough quartz and generally rounded or sub-angular. The clay percentage is 7 per cent of the total.

Gay property.—On the south side of the Central of Georgia Railway, and within 500 feet of the track, although on the opposite side of a small branch valley, on the property of H. A. and F. M. Gay, Sr., a deposit of gravel occurs near the top of the hill. From 4 to 6 feet of gravel outcrop in the plantation road cut just above the Mercer Mill site, and in a well at the house at the top of the hill 4 feet is shown. In gullies on the west side of the same hill overlooking the clay, gravel similar to that east of the railroad, in the pit, is shown in each of two streaks separated by 3 or 4 feet of clay. Apparently about 10 acres at least are underlain by workable gravel from 4 to 7 feet thick, the cover increasing from a foot to an unknown thickness as the center of the hill is approached.

On the hill, east of the railroad, and 200 yards north of the old pit, separated from it by a ravine, some gravel of unknown thickness and extent is exposed 10 feet above the road level. This material was formerly prospected, and it is reported that good gravel was found. These pits have since filled up and only the gravel covering the surface of probably 10 acres could be noted. In an old pit along the railroad, a few hundred feet west, no gravel of any value was seen.

Lampley property.—On the H. Lampley property, adjoining the Gay plantation on the east, 6 feet of gravel of fairly good quality outcrops on the old cut-off road leading from Georgetown to the Fort Gaines road, about a quarter mile from the latter road. Part of the same gravel is exposed on the opposite side of the hill, on the Fort Gaines road. At this point the pebbles are small, the clay content very large, and the quality much poorer than that further west.

Tobananee Creek.—Excellent gravel is being obtained from the bed of Tobananee Creek, a quarter mile from Chattahoochee River on the F. M. Gay, Sr., plantation. The gravel is about 2 feet thick in the stream bed and the stream 25 feet wide. A finer-grained gravel occurs in small bars of a few hundred square feet in extent along the stream. The pebbles are of rounded and sub-angular quartz, very tough, and generally white or gray. Sample *T-224* shows a fineness modulus of 5.96, with 66 per cent of it retained on the 4-mesh screen. The gravel is scooped up out of the creek bed and placed in a bin from which trucks are loaded and the gravel used for construction work in Eufaula, Ala., just across the river. The gravel is of very good quality.

Quitman County Farm.—Gravel of good quality for road purposes occurs on the Quitman County Farm at several places. In a road cut on the Georgetown-Cuthbert road at the crest of the hill, 1.3 miles from Georgetown, 4 feet of sandy and clay gravel are exposed. The gravel, although of good quality, is variable in thickness and extent.

Other deposits.—Some clay gravel occurs in a number of places on the second terrace of Chattahoochee River north and south of Georgetown, but distance from railroads will prohibit its use for a long time. Just west of Georgetown, as the Eufaula road descends to the first terrace of Chattahoochee River, from 3 to 6 feet of clay gravel are exposed with from 1 to 10 feet of cover. The gravel is used for road-making and is of good quality.

RANDOLPH COUNTY

The Claiborne sands and clays form the surface material in an irregular belt in the western and central parts of Randolph County, and in the southern part the Ocala limestone is found. No commercial sand or gravel is produced in the county, although parts of the county, particularly in the west and north, contain extensive sand deposits.

Cuthbert.—Very little sand of any value is found near Cuthbert. The local supply is obtained from small deposits near small streams and branches and is usually rather fine-grained.

Near Shellman, in the eastern part of the county, surficial sand from 2 to 5 feet thick occurs near the Central of Georgia Railway. This sand is usually too fine-grained and loamy to be of use except for mortar or plaster purposes. Similar sand, 3 to 5 feet in thickness, is found along Pachitla Creek.

Coleman.—An extensive sandy area begins half a mile southwest of Coleman. The sand is exposed in road cuts to a maximum thickness of 6 or 7 feet, but it is fine-grained and somewhat loamy. No large deposits occur close to the railroad. In this vicinity shallow water wells generally encounter a medium-grained yellow sand, at depths of from 3 to 15 feet below the surface, which ranges from 15 to 30 feet in thickness. Such sand appears to be widespread even in the western and northern parts of the county and is probably of Midway and Wilcox age. It is possible that prospecting near railroad lines may reveal deposits of such sand with an overburden thin enough to warrant commercial operation.

Benevolence.—In the northern part of the county close to the Georgia, Florida & Alabama Railway, surficial deposits from 3 to 6 feet thick occur. The sand is particularly prominent near Barge's Mill Creek where it is gray and medium-grained. This sandy area extends with interruptions across the northwest corner of the county through Springvale. South of the Central of Georgia Railway, about two miles from Morris Station, and in the western part of the county, the gray and yellow sand attains a thickness of 20 feet or more over large areas.

RICHMOND COUNTY

Both sand and gravel are produced commercially in Richmond County, and large gravel pits are also operated by the county for road material. The gravels usually lie directly upon the ancient schists and constitute part of the belt of Fall Line gravels. Sand is obtained as a product of gravel washing, or from the sand hills along the Georgia Railroad near Wheless Station.

Richmond County gravel pit.—Richmond County owns a large gravel pit half a mile east of the Savannah public road, opposite the cotton oil mill, near the Central of Georgia Railway. The gravel is used principally for road building throughout the county, but sand is also sold locally for concrete aggregate. The pit covers over 10 acres and is full of water to a depth of from 10 to 28 feet, which can not easily be drained. The gravel is mined by a Crawford excavator made by the Lidgerwood Manufacturing Company, and equipped with a 1½-yard drag bucket and a 60-foot boom. (Plate IV-A.) The excavator is located on the bank above the pit and is driven by a 25-horsepower steam engine. The gravel and sand are scooped out of the pit and piled on the bank from which it can be conveniently loaded into the 3-ton trucks used by the county. The excavator when pushed can handle a yard a minute, but ordinarily half a yard a minute is a better average. The machine is equipped with 160 feet of steel cable and has dug 25 feet below its grade. The sand and gravel are loaded on the trucks by a Keystone excavator with a skimmer dipper. (Plate III-A.)

Section at Richmond County gravel pit, Augusta

	Feet
Sandy, loamy soil and cover	0–3
Clay gravel, pebbles from ½ to 2 inches and highly cemented	5–7
Yellowish sand	5–6
Red, clayey sand and gravel	(?)
Pure white sand	(?)

The red, clayey sand and the white sand beneath, are under water, but their occurrence was reported. The cover is thickest west of the pit, where it ranges from 3 to 4 feet, elsewhere it is generally about 2 feet thick. The faces of the pit stand well, partly because of their long exposure to the weather. The surface contour is flat.

According to Captain Fulghum, county superintendent of roads, the pit was opened about 1909, and the excavator has been at work since 1918. The natural sand and gravel proportion as mined is about equal, and this material is used directly on the roads. It has been the experience in the county that if gravel alone is used on the roads, with too much clay, they wash out. The good roads of the county attest the excellence of this natural mixture.

Sample *T-42*, taken from the gravel face at the western end of the pit, shows a fineness modulus of 4.97 and 55 per cent coarser than 4 mesh. The pebbles are mostly of tough angular to sub-angular quartz; a few decayed feldspar pebbles also occur.

Georgia Sand and Gravel Company.—The Georgia Sand and Gravel Company, in charge of E. W. Hancock, produces an excellent grade of washed sand and gravel for concrete aggregate and other purposes. The plant is located at the south end of the same pit from which the county gets its gravel, the western half of which is owned by this company. A 6-inch, 30-horsepower, centrifugal pump made by the Augusta Iron Works has been recently installed to remove the sand and gravel from the large pit and convey it 250 feet southward to a small pond at the foot of the screening plant. (Plate V-A.) In June, 1920, the pump was sucking the sand from a depth of 26 feet. The mixture deposited in the small pond is then raised 24 feet by a 4-inch, 25-horsepower pump to the top of the washer. (Plate VI-A.) The material can be pumped at the rate of 200 yards per 10-hour day. The sand, gravel, and water from the pit pass over two sloping, concentric, cylindrical trommels, making 12 revolutions per minute and driven by a 2-horsepower gasolene engine, which separates the gravel and allows it to fall into a car or small stock pile. The openings in the inner trommel are half an inch, and the material retained on this is sold as gravel; the outer trommel has openings of $\frac{3}{4} \times \frac{3}{16}$ inch, and the sand is divided into two sizes: that retained on the outer trommel and that passing it. The sand passing the $\frac{3}{16}$-inch mesh goes in to wooden settling banks from which the clay and water passes into a small pit south of the washer. When the settling bank is full it automatically dumps the sand into a freight car on the track below.

Sample *T-41* represents the gravel product. A mechanical analysis shows a fineness modulus of 5.52 and 42 per cent coarser than 4 mesh. About 5 per cent of this material is feldspar and the rest sub-angular quartz pebbles. The gravel composes about 25 per cent of the product pumped from the pit. Most of the gravel is sold locally at the pit.

Sample *T-43* is typical of the sand passing the $\frac{3}{16}$-inch trommel and shipped as concrete sand. It consists essentially of angular quartz grains with some feldspar. The fineness modulus is 2.49, and 89 per cent is coarser than 48 mesh. It contains only a trace of organic matter. Mortar tensile strength tests of this sand made by the U. S. Bureau of Public Roads gave 127 per cent and 115 per cent of normal at 7 and 28 days, respectively.

Analysis of sand from pit of Georgia Sand and Gravel Company, Augusta, T-45

Loss on ignition	0.06
Soda (Na_2O)	0.06
Potash (K_2O)	0.10
Lime (CaO)	0.21
Magnesia (MgO)	0.03
Alumina (Al_2O_3)	2.30
Ferric oxide (Fe_2O_3)	0.78
Manganous oxide (MnO)	trace
Titanium dioxide (TiO_2)	1.61
Silica (SiO_2)	94.97
Rarer earths	0.00
Total	100.12

Augusta Silica Mining Company.—The Augusta Silica Mining Company, in which Messrs. Sommers and Rox of Augusta are interested, has contracted with Richmond County for the sand in the county pit. When visited in June, 1920, preparations were under way for installing a modern washing and screening plant, the sand was to be recovered with a crane having a ¾-yard clam-shell bucket.

Williams property.—South of the Richmond County pit, Williams (colored) owned 30 acres which is underlain with sand and gravel of unknown extent and thickness.

A well on the Augusta Abattoir property, 800 feet north of the county pit, is said to have encountered 80 feet of sand and gravel. None of the excavating by either the county or the Augusta Sand and Gravel Company at this pit has penetrated the sand and gravel, although a depth of over 30 feet has been reached.

Oates property.—A gravel pit formerly operated by the county is located on the Oates property on the Savannah road, 2 miles from Augusta. The pit covers about an acre, and the overburden ranges from a few inches to 5 feet of sandy clay near the top of the hill and has a few pebbles in it. The gravel is from 5 to 10 feet thick in the pit, has a sandy clay matrix, and is composed of quartz and feldspar pebbles up to 3 inches in diameter. Clay stringers occur through the upper part of the gravel, and the pebbles are smaller although thicker, in the lower part. The extent of the deposit is uncertain, but it is probable that workable gravel underlies 5 acres in this vicinity. Sample *T-46* from this property has a fineness modulus of 4.35 and 42 per cent coarser than 4 mesh. The clay content is 13.7 per cent.

Wheless Station.—On the south face of the hill upon which Camp Hancock was located considerable surficial sand occurs as well as coarser, yellowish sand concentrated in large quantities in gullies. Sand from these gullies is used for local work in nearby parts of Augusta.

About a third of a mile north of Wheless Station, where gravel for camp construction was stock-piled, a pit was opened in Cretaceous sand for use during the building of the camp. The pit covers a third of an acre, and the sand ranges from 3 to 10 feet thick. It is coarse-grained and slightly clayey but of excellent quality. On the north side the sand merges into white and red clay. A loading trap 20 x 20 feet and 10 feet high has been constructed. Some sand is still used from this pit.

Hepzibah.—At the pit of Albion Kaolin Company near Hepzibah the following section is exposed above the white clay:

Section at pit of Albion Kaolin Company, Hepzibah

	Feet
Sandy, clayey soil	1
Red clay	3
Red clay gravel, pebbles from ½ to 2 inches	2–6
Pure white clayey sand	10–12
White clay	20

An analysis of the white sand above the clay shows 23 per cent clay.

Analysis of washed white sand from Albion Kaolin Company's pit, Hepzibah

Moisture at 100 °C	0.00
Loss on ignition	0.55
Soda (Na_2O)	0.14
Potash (K_2O)	0.21
Lime (CaO)	0.00
Magnesia (MgO)	0.02
Alumina (Al_2O_3)	0.61
Ferric oxide (Fe_2O_3)	1.76
Manganous oxide (MnO)	trace
Titanium dioxide (TiO_2)	0.45
Silica (SiO_2)	95.92
Total	99.74

Some deposits of gravel have been reported from the vicinity of Hepzibah, but none of them are of value except as local road material.

Other deposits.—It is reported that preparations are under way to pump sand from Savannah River below the Center Street bridge with a 6-inch pump, but when visited in June, 1920, no sand was being produced.

Numerous other deposits of sand and gravel occur in Richmond County, but detailed investigation of them is impossible at this time.

SCHLEY COUNTY

Although thin deposits of surficial sand are common throughout Schley County, especially in the northern part, and are useful in the construction of sand-clay roads, very little good sand is found. Local supplies for Ellaville and other towns in the county are generally obtained from accumulations in small branches or gullies. The larger streams such as Buck, Richland, Muckalee, and Camper creeks, have larger amounts along their courses.

A few thin deposits of clayey gravel occur throughout the county, especially on terraces and terrace slopes of the streams. A small deposit of this kind, about 3 feet thick, occurs on the Dixie-Overland Highway, a quarter of a mile east of Putnam.

In the northern half of the county, gullies expose white and yellow clayey, fine- to medium-grained sands of the Ripley formation; and in the southern half clayey sands of the Midway formation are exposed in gullies. This sand will afford sources of local supply in the future where the cover of sandy clay is not excessive.

SCREVEN COUNTY

Screven County, particularly in the southern part, has a thin veneer of fine-grained sand ranging from a few inches to several feet in thickness. Local thickenings of this surficial sand constitute the rather meager sources of building sand. Such deposits can easily be found near the towns, but the sand is usually too fine-grained to make the best concrete.

Savannah River, forming the east boundary of the county, and Ogeechee River, on the west, have large bars of sand in and along their courses, and that along Savannah River may, in the near future, be used for commercial purposes. The larger creeks and their tributaries, particularly Brier and Beaverdam creeks, have some sand in their courses and during flood periods have deposited irregular amounts along their banks or bottoms.

Small amounts of gravel have been noted in road cuts throughout the county, but none are believed to be of any value.

STEWART COUNTY

Probably the heaviest beds of gravel in Georgia are found in Stewart County on the Chattahoochee River terraces, although neither sand nor gravel is being produced in the county at this time.

Booth property.—Ishmael Booth (colored) owns lot 226 on which is a large amount of gravel. The deposit is 1¾ miles northwest of the Seaboard Air Line Railway and 3½ miles north of Omaha. One deposit, lying on a small hill 1,000 feet southeast of Booth's house, has at least 4 acres of sandy gravel averaging 7 feet thick and having a cover ranging from 1 to 5 feet. A small pit has been opened in the deposit and the gravel hauled as far as the Bradley plantation, 3 miles away. Sample *T-228,* from this deposit, has a fineness modulus of 5.63 and 66 per cent coarser than 4 mesh. The clay content is 7 per cent. The largest deposit on the Booth property lies 0.3 mile east of the first deposit and is well exposed in gullies.

Section on Ishmael Booth property, 3½ miles north of Omaha

	Feet
Sandy clay soil cover (averaging 3 feet over 6 acres)	0–10
Sandy gravel, pebbles from ½ to 2 inches	8
Clay gravel, pebbles from 1 to 2 inches	6
Clay gravel, pebbles from ¼ to 1 inch	3

The total extent of this deposit is uncertain, but it is probable that an average of 12 feet of gravel with an average cover of 6 feet underlies at least 10 acres of the property. Sample *T-229,* representative of this deposit, shows a fineness modulus of 5.88 and 65 per cent coarser than 4 mesh. The clay content is 6.4 per cent.

Pope property.—In the northern part of lot 352, owned by Warren Pope and adjoining the Booth property, considerable gravel is exposed. Gullies 300 yards south of Booth's deposit and 100 yards north of Armstrong branch, show at least 10 feet of gravel.

Section on Pope property, lot 352

	Feet
Gravel, pebbles from 1 to 3 inches, the upper half sandy and the lower half clayey	11
Red, clayey sand	5
Red, clayey gravel, pebbles up to 1 inch	1–4

The cover is of sand and clay and in this vicinity ranges from a few inches to 10 feet, the average being about 5 feet. This deposit continues southwestward along Armstrong branch and appears near the top or part way up the enclosing hills on both sides of the stream. Its average thickness is about 10 feet, and the cover may be as great as 30 feet, although the average cover over 40 acres would not exceed 5 feet. The upper part of the gravel is generally sandy, indicating that the original clay matrix has been washed away; at a depth of from 2 to 5 feet, however, the matrix becomes clay. This deposit is from 1 to 1½ miles north of the Seaboard Air Line Railway.

Battle property.—A pit was formerly operated on the old Battle plantation 0.8 mile north of the Omaha-Union road and 2.4 miles east of Omaha. The deposit is 250 yards south of the railroad and about 50 feet above it.

Section at gravel pit on old Battle plantation, 2.4 miles east of Omaha

	Feet
Cover of red, clayey sand	5–15
Gravel, pebbles from 1 to 2 inches, with lenses of red, clayey sand	4–7
Coarse, white sand	0–3
Coarse, yellow, somewhat clayey sand	3–5

The pit covers 4 acres and has not been worked since about 1900. Its operation was discontinued due to the increasing overburden at the deposit and also because of the steep grade leading from the main line to the pit. There still appears to be considerable gravel in this vicinity however. Sample *T-227*, representative of the gravel in this pit, shows a fineness modulus of 6.19 and 68 per cent coarser than 4 mesh. The clay content is 7.6 per cent. Gullies from 100 to 400 yards south of the pit show from 3 to 7 feet of gravel in irregular streaks, composed mostly of small pebbles and usually with from 3 to 7 feet of overburden.

Fitzgerald property.—A small sand-gravel pit has been opened for road material on the W. A. Fitzgerald property, 1.2 miles south of Omaha, on the Florence road. (Plate XIII-A.) A maximum of 5 feet of clayey sand-gravel is exposed in the pit, which is underlain by clay. The gravel appears to thin out toward the north but may continue a short distance southwest and westward. Just west of the road at this point at the edge of the upper terrace overlooking Chattahoochee River, 4 feet of rather thin clay gravel is exposed in a plantation road cut. Numerous other shows of gravel, apparently of small thickness, occur on the face of the bluff overlooking the river bottom and the railroad. Sample *T-226,* taken from the pit on the Florence road, shows a fineness modulus of 5.75 and 69 per cent coarser than 4 mesh. The clay content is 7.1 per cent. Although a large acreage is underlain with gravel on this property, very little appears to exceed 3 or 4 feet in thickness.

Excellent coarse sand, although somewhat clayey, is exposed at the railroad in a gulley, 3 miles southwest of Omaha station. The sand is at least 8 feet thick, but it all lies lower than the railroad grade.

Fort Hill.—On the River Road, 0.6 mile northwest of the Omaha depot, gravel shows in road cuts on Fort Hill. The gravel appears to be from 3 to 5 feet thick over a maximum of 4 acres.

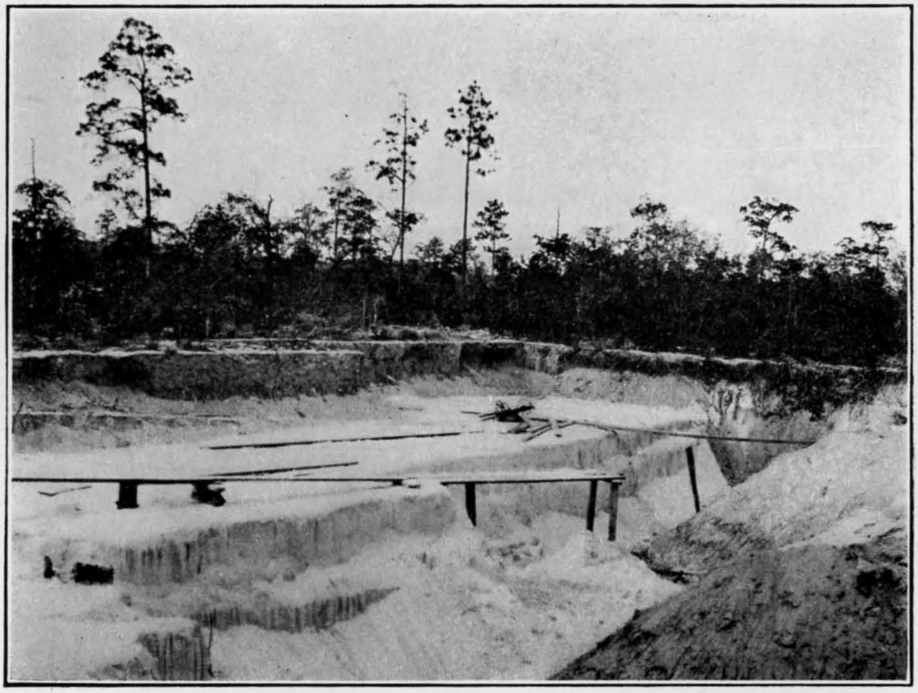
On the same road, 1.2 miles north of Omaha, sandy gravel, having pebbles from ½ to 1 inch in diameter, outcrops near the top of a hill overlooking a small branch to the northward.. The maximum thickness is about 7 feet, and the extent of the deposit is uncertain.

Kubo property.—On the Lee Kubo property, 1.6 miles north of Omaha on the River Road, is a 1-foot bed of coarse, cobbly gravel overlain by from 6 to 8 feet of fine-pebbled clay gravel, the upper half of which is sandy. A sandy clay cover increases to a maximum of 15 feet toward the top of the hill. Beneath the upper gravel is a 4-foot streak separated from the first by 5 feet of sandy clay. Gullies, 800 feet west of the road, showed practically no gravel.

Hannahatchee Creek.—At Omaha, Hannahatchee Creek is 30 feet wide and has a large amount of excellent, coarse sand and quartz gravel well suited for concrete purposes. The deposit is from 2 to 5 feet thick in the stream bed and underlain by black marl of the Ripley formation. The deposit is said to continue upstream for at least a mile and down to Chattahoochee River. Sample *T-230* shows a fineness modulus of 5.24 and 48 per cent coarser than 4 mesh. The deposit is especially prominent where the Seaboard Air Line Railway crosses the creek.

Sand streams.—On the Florence-Lumpkin road, 9 miles west of Lumpkin, a remarkable deposit of yellow sand may be seen which has been washed down during heavy storms from a number of deep gullies 1 to 2 miles further east. The sand-stream covers over 15 acres and is said to be as much as 20 feet thick. The sand is me-

A. GENERAL VIEW OF SAND AND GRAVEL PIT, LUMBER CITY SAND & GRAVEL COMPANY, 2 MILES NORTH OF LUMBER CITY, TELFAIR COUNTY



B. GLASS SAND PIT, HINSON SAND MINES, 1 MILE NORTHEAST OF LUMBER CITY, TELFAIR COUNTY dium-grained and of fairly good quality. During the heavy storm of December, 1919, the sand came down in such volumes as to partly wash out and cover up the road so that it was necessary to move the road some distance northward.

Other deposits.—A belt in central Stewart County is underlain by the Providence and Cusseta sand members of the Ripley formations. This sand is well exposed in numerous gullies along the Florence road, 8 miles west of Lumpkin. The upper 100 feet of these gullies are a yellowish-white, rather fine-grained sand of little value either in building or in glass making, due to its impurities.

In the eastern part of the county near Lumpkin and Richland, concentrations of sand in small gullies and streams generally afford the local supply for building purposes.

SUMTER COUNTY

Numerous deposits of sand suitable for building purposes occur in Sumter County, but none have been opened yet on a shipping basis.

Walter Rylander pit.—The Rylander pit is east of the Smithville road, 1.7 miles southwest of Americus, and a quarter mile south of the Seaboard Air Line Railway. The pit covers about an eighth of an acre, and the sand is teamed or trucked to Americus for local use. It is white to yellow with clay lumps and layers ranging from the thickness of a knife to half an inch and occurring at intervals of from 1 to 5 inches through the sand.

Section of Rylander pit, southwest of Americus

	Feet
Red, sandy clay exposed in gullies above the pit	10
Reddish-brown and white, fine-grained sand; velvety, and having some gritty layers	3
Medium- to coarse-grained, white, and yellow sand with clay and sandy clay strata, cross-bedded	10
Brown to red, clayey sand at bottom of pit	1

The overlying clay may be a hindrance in the future development of the pit, although a large quantity of sand exists in this vicinity which can be obtained with very little removal of overburden.

Sample *T-231* shows a fineness modulus of 2.26 and 80 per cent of the sand coarser than 48 mesh. The organic content factor is insignificant. The sand is made up entirely of sub-angular quartz grains.

Council pit.—The Council sand pit is located near the corner of Ashby and Poplar streets in Americus. The pit covers about half an acre and is situated near the head of one of the numerous gullies in this part of the county. Twenty feet of strata are exposed.

Section at Council pit, Americus

	Feet
Soil, dark gray to black	1
Yellowish-orange, clayey to silty sand	6–8
Coarse- to medium-grained, yellowish-orange sand having small, brown clay balls and irregular streaks of dark, sandy clay	8–10
Coarse, angular, white to yellow sand having only a small clay content	4–5

The best sand occurs in the lower 4 feet of the pit and this may be obtained if care is taken in loading. Sample *T-232* is a general sample of the lower 14 feet. The fineness modulus of this sample was 1.78, and 64 per cent was coarser than the 48-mesh screen. The sand is reddish-brown and composed of sharp, highly stained quartz grains. The sand has only a faint trace of organic matter.

Sand similar to that found near Americus is widespread over the county beneath the surficial sandy clays. It can be best observed in gullies, but the usual depth of overburden is such as to prevent extensive production of the sand in most of the localities in which it is found.

Flint River.—Flint River, which forms the eastern boundary of the county, has great quantities of medium-grained brown sand of fairly good quality. The most favorable place for commercial production is at the Seaboard Air Line Railway crossing in the southeast corner of the county.

Large quantities of fine- to medium-grained, yellow to gray sand occur in the river swamp, having a maximum thickness of 10 feet in the bottom of intermittent lakes along the river. Such deposits are of value only for construction purposes at points close to the river where other supplie sare not available. The results of tests of similar sand from the east side of Flint River in Dooly County are given on page 191.

TALBOT COUNTY

Along the Atlanta, Birmingham & Atlantic and the Central of Georgia railways, in the southern part of Talbot County, a number of sand pits are in operation, and a great quantity of sand is shipped annually to all parts of Georgia and also to Alabama and Tennessee. The surface of the sand area is undulating and even slightly hilly. Sand is generally thickest under the hills or ridges of the area, and in the valleys the underlying clay is likely to be exposed or come so close to the surface as to eliminate the sand for commercial purposes. Talbot County produces more sand than any other county in the state.

PITS ALONG THE CENTRAL OF GEORGIA RAILWAY

J. R. Hime Sand Company.—The pit of the J. R. Hime Sand Company, in charge of O. A. Nix, is located a mile and a half east of Junction City on the Atlanta, Birmingham & Atlantic Railway and has been in operation since 1909. The area worked over is about 5 acres, and the maximum height of the face is 22 feet, although the average height is 15 to 16 feet. The sand in the upper 6 to 8 feet is fine-grained and gray or yellow but becomes darker and coarser with depth. The lower 8 or 10 feet has the peculiar wavy stratification made by layers of reddish, clayey sand, but these are not so marked as in the Crawford County pits. The lower 2 to 5 feet of the sand exposed at the face and which extends for at least two feet in places beneath the floor of the pit, is fairly coarse-grained and white. It is used for molding and concrete work and has been shipped as far as Nashville, Tenn., for foundry purposes. Sample *T-77,* representing the lower 4 feet of the deposit, shows a fineness modulus of 1.72 and 60 per cent coarser than 48 mesh.

The sand is mined by a drag-line excavator with a one-yard Sauerman drag-bucket operated by a 30-horsepower Mondy hoisting engine. (Plate III-B.) The hoist is placed on a platform built in front of the pit face, the spur track passing between the platform and the face, and the drag-bucket is pulled toward the platform and the sand unloaded over a car, the cable passing around a pulley attached to an A-frame which can be easily moved when the sand is removed from one place. The range of the drag is now about 200 feet.

The sand has also been loaded from the face by a Haist Wagon Loading Machine, requiring 8 horsepower. The device is 15 feet high and has 20 buckets each having a capacity of 3 cubic feet. With this machine two men can easily fill a car in two hours, although with fast working it has been done in 45 minutes. One man is located at a foot of the machine to keep it supplied with sand and close to the face, and the other works in the car keeping the sand distributed as it enters.

To recover the coarser sand near the base of the pit so that a high-grade washed sand can be put on the market, a 12-horsepower centrifugal pump, with a 6-inch intake, has been used which sucks the sand from a pond in the center of the pit kept supplied with water. The sand from this pit is sold direct to the consumer in Atlanta and other markets along the Atlanta, Birmingham & Atlantic Railway.

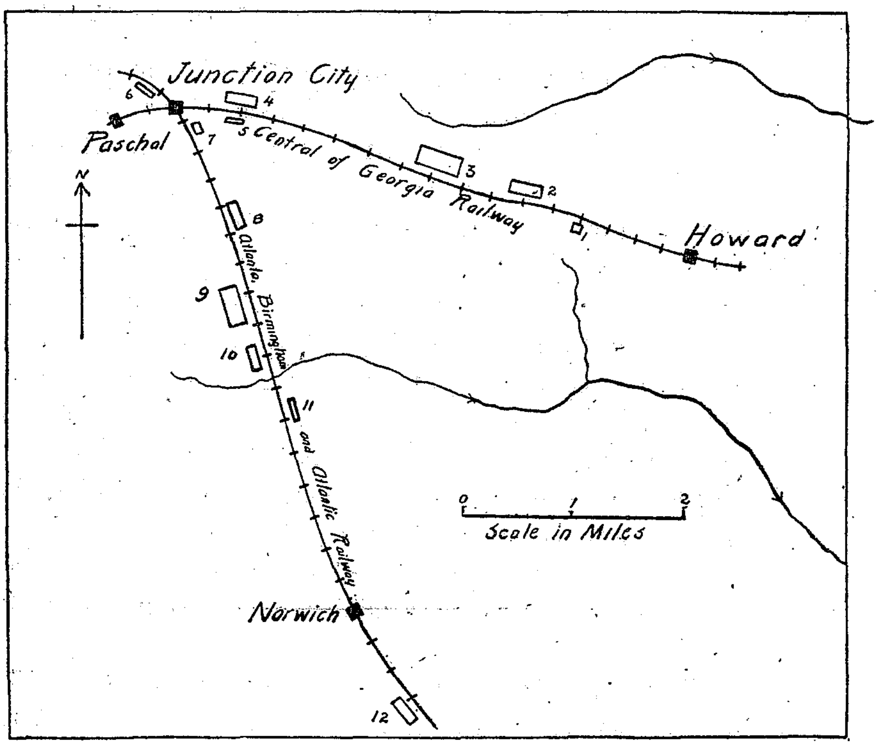


Fig. 13. Sand pits along Central of Georgia and Atlanta, Birmingham & Atlantic railways near Junction City, Howard, and Norwich in Taylor and Talbot counties.
1, Washer, Kirkpatrick Sand & Cement Co.; 2, Central of Georgia pit; 3, 8, Kirkpatrick Sand & Cement Co. pit; 4, 5, J. M. Heath pits; 6, L. J. Downs pit; 7, Alexander pit; 9, 10, J. R Hime Sand Co. pit; 11, Morningstar pit.

About 2¼ miles southeast of Junction City, and below the present Hime pit, a large pit is located which was formerly worked by the J. R. Hime Sand Company. The sand face is poorly exposed due to caving, but the material appears to be similar to the usual run of sand in this region. Although having a little higher clay content and somewhat finer grains than those in the present pit, from 10 to 15 feet of sand show up in the pit, and the face is several hundred yards long. Just east of the pit a branch valley cuts through the sand, and it is possible that testing closer to the valley may disclose coarser stream sand.

Morningstar pit.—Two miles east of Junction City, L. E. Morningstar was preparing to ship sand when visited in June, 1920. At that time grading for the spur track was under way and plans made for the installation of a mining and treatment plant.

Kirkpatrick Sand and Cement Company.—The Kirkpatrick Sand and Cement Company, with offices at Birmingham, Ala., leases sand land from J. M. Heath, of Talbotton, and operates a pit by colored hand labor, half a mile southeast of Junction City on the Atlanta, Birmingham & Atlantic Railway. The pit has been worked since 1913, and about 5 acres of sand have been removed. The face ranges from 9 to 15 feet in height over a length of 800 feet, and holes dug at the bottom of the pit indicate a continuation of the sand downward for 4 or 5 feet over part of the pit at least, particularly that within 75 to 100 feet of the face. The upper 6 feet of the face is fine-grained, gray, and a little silty, but it becomes coarser and cleaner in the lower half of the pit. The lower 5 feet, as exposed at the face, is made up of distinct wavy strata of reddish clayey sand an inch or two thick, separated by crusts and layers of white, coarser sand, from 2 to 5 feet thick. The best sand is at the east end of the pit. The underlying mottled sandy clay comes to the surface along the railroad at the southeast end of the worked-out portion of the pit. South of the railroad the surface gradually rises indicating a considerable thickness of sand.

Sample *T-81,* typical of the lower 6 feet of the pit and taken from the eastern end of the face, is yellowish white, clean, and has a fineness modulus of 1.38 with 44 per cent retained on the 48-mesh screen. The organic matter shows a color value of 200.

Surface indications appear favorable for a considerable extent and thickness of sand along the railroad just west of the Kirkpatrick pit.

Alexander pit.—The Alexander sand pit is located on the Altanta, Birmingham & Atlantic Railway just east of the depot at Junction City, on the property of C. W. Moore of Junction City, leased by Edgar Alexander of Atlanta and managed by J. E. Boswell. The face is from 10 to 12 feet high, the upper 6 feet being a fine-grained, gray sand, and the lower half is stratified, the strata consisting of alternating layers of white, medium-grained sand, 2 inches thick, and one-inch layers of a reddish, somewhat clayey sand. The lower foot or two is still coarser, although not so white as that in some of the other pits. Sample *T-78* represents the entire face of the pit and shows a fineness modulus of 1.82 with 63 per cent coarser than the 48-mesh sieve. The organic matter shows a color value of 200. The production averages about two cars a day, and the cars are loaded by hand labor.

Downs pit.—The L. J. Downs' pit is located on the Atlanta, Birmingham & Atlantic Railway, a quarter of a mile west of Junction City near the western margin of the sand belt. The pit floor covers almost two acres, and the face is from 10 to 12 feet high. The upper 6 feet is a fine-grained, wind-blown sand, gray to yellow in color, and the lower half is stratified with alternate layers of yellow sand and reddish-yellow clayey sand. The lower 4 feet consists of a fairly coarse stratified sand of good quality. Below this a coarse, sandy clay of unknown thickness is met with that might be suitable for use as a coarse foundry sand. The pit has been in operation since 1907 and produces from one to two cars daily, which is shipped mostly to Atlanta.

Morgan property.—W. K. Morgan owns about 100 acres northeast of the junction of the Atlanta, Birmingham & Atlantic Railway and the Central of Georgia Railway at Junction City. Some of this has thick deposits of sand similar to that in the pits in this locality, although no sand is being dug from it. The greatest thickness lies on a ridge extending approximately north and south about 1,200 feet west of the Central of Georgia Railway tracks. In a well at the Morgan residence, 21 feet of sand was passed through, and in a test hole, a quarter of a mile northwest of the house, 25 feet of sand was said to have been encountered. Sand from the upper 4 or 5 feet of the property as shown in a hole dug in the writer's presence was of a fairly good quality, but below this point the sand becomes somewhat finer-grained. The deeper test hole and the well showed this type of sand to continue to within two or three feet of the red underlying sandy clay, where it becomes much coarser. A small stream, affording a constant water supply, flows along the western edge of the deposit. Tests close to the stream showed a coarser sand than that further up on the hill.

PITS ALONG THE CENTRAL OF GEORGIA RAILWAY

Kirkpatrick Sand and Cement Company.—A pit of the Kirkpatrick Sand and Cement Company is located on the Central of Georgia

Railway, two miles west of Howard on a 400-acre tract owned by that company. The face is from 12 to 40 feet high and about 1,500 feet in length. (Plate XIII-B.) The area already worked covers over 20 acres. The upper part of the face shows 8 feet of fine-grained, grayish-yellow sand, somewhat loamy near the top, and which has been deposited in its present position by the wind. Below the upper 8 feet the sand becomes somewhat coarser and has a corrugated or wavy appearance, due to many strata of reddish-brown clayey sand and has a few clay lumps scattered through it. This stratification has probably been caused by settling of the sand in water either along the shore of an ancient estuary or on the flood-plains of large streams.

The thickness of the stratified sand ranges in different parts of the pit from 5 to 30 feet. It grades into a red, clayey sand at the bottom of the pit from 1 to 4 feet in thickness, which in turn may merge into a fine, white sand said to be from 1 to 3 feet thick. None of the white sand was exposed at the time of writer's visit in the spring of 1920.

Veatch[1] gives a section of this taken in 1910, in which he notes the white sand:

Section at Kirkpatrick Sand and Cement Company's pit west of Howard

Surficial sand	Feet
5. At the surface, fine-grained gray or brownish sand	25
4. Light yellow sand	
3. Almost white sand showing evidences of water stratification	
2. Ferruginous sand containing a very small percentage of clay	5
1. White sand	

Microscopic examination of sample *T-82*, representative of the entire face of the deposit, and in fact of all the yellow sand throughout the Taylor and Crawford counties sand region, revealed sub-angular grains of slightly stained quartz, becoming angular as they decreased in size. A small amount of mica was noted in very fine flakes and also a few fragments of feldspar, generally considerably decomposed. Black sand, largely ilmenite, with a few grains of magnetite, occurs in the sand and usually passes the 65-mesh screen.

1 Veatch, Otto, and Stephenson, L. W., Geology of the Coastal Plain of Georgia: Georgia Geol. Survey, Bull 26, p. 453, 1911.

The thickness of the stratified sand ranges in different parts of the pit from 5 to 30 feet. It grades into a red clayey sand at the bottom of the pit from 1 to 4 feet in thickness, which in turn may merge into a fine, white sand said to be from 1 to 3 feet thick.

The sand is loaded by means of a 50-ton Browning locomotive crane having a bucket of one yard capacity. The boom is 38 feet long, and a 40-horsepower engine and boiler supply the power. A 50-ton car can be loaded in 20 minutes with the crane. The face is sufficiently long and the sand so thick that a thousand cars can be loaded at each shifting of the track. Formerly a steam shovel was used, but due to the height of the face it was found necessary to install the crane.

Washer.—The washer, through which part of the sand is passed to increase its silica percentage for steel foundry purposes, is located a half mile east of the pit. It consists of 5 worm screws 12½ feet long, each fed with water from 1¼-inch pipes supplied by a 5-inch main through which the water is raised at the rate of 150 gallons per minute from an impounded stream, 122 feet below vertically and 2,200 feet distant horizontally. (Plate VII-B.) The sand is allowed to enter the washer from the car above and after being washed is elevated 28 feet by steel buckets attached to an endless belt to the car to be filled. Power is supplied by a 15-horsepower Foos kerosene engine, which consumes 10 gallons of the fuel daily. About four hours are required to load a 40-ton car. From 20 to 35 per cent of silt and other material are removed in the washing. The unwashed sand (see *T-82*) has 43 per cent coarser than the 48-mesh sieve, and the washed sand (see *T-83*) has 61 per cent coarser than 48 mesh; the tailings, or silt and clay washed from the sand (see *T-84*), has 25 per cent coarser than 48 mesh. These tailings appear to be well suited for asphalt paving sand which requires material ranging from 50 to 80 mesh in size. Most of the washed product is shipped to foundries in Alabama and Tennessee.

Central of Georgia Sand Company.—The Central of Georgia Sand Company, owns a sand pit on the Central of Georgia Railway, 1½ miles west of Howard. The face shows a maximum height of 30 feet and is about 800 feet long. The sand is, in general, similar to that in the Kirkpatrick pit except that the lines of stratification are almost invisible, the whole face presenting an unbroken mass of grayish-yellow sand, becoming somewhat darker and a little coarser beneath the upper 3 or 4 feet, until the bottom of the pit is reached. Here the commercial sand grades into a reddish-brown, clayey sand from 1 to 3 feet thick, beneath which a white sand is said to occur. Sample *T-87*, representative of the sand in the lower 12 feet of the pit, which is used for molding, has a fineness modulus of 1.70 and 59 per cent coarser than 48 mesh. Sample *T-88*, typical of the white sand at the east end of the pit, has a fineness modulus of 1.69 and 64 per cent coarser than 48 mesh. A general sample tested at the Georgia School of Technology laboratory gave a concrete strength ratio of 90 and 97 per cent at 7 and 28 days, respectively.

The face is long enough to permit loading 150 cars at one movement of the track. The cars are loaded by a Williams' crane having a ¾-yard bucket. The bucket is equipped with an automatic digging arrangement, and a 40-ton car can be easily loaded in 20 minutes. The sand from this pit is shipped principally to foundries in Atlanta and Birmingham, Ala., to marble works for sawing purposes, and to Birmingham for mortar and concrete aggregate.

Carlyle property.—Along the Central of Georgia Railway between Paschal and Geneva, heavy beds of fine-grained, gray sand occur of unknown thickness, principally on land owned by T. J. Carlyle.

Other deposits.—On the Central of Georgia Railway, 2.3 miles west of Howard by road at the 227-mile post, 15 feet of yellow sand similar to that in pits further west are exposed for 800 feet in the cut. One third of a mile further west of this point the land again rises, and although so great a thickness of sand is not exposed, yet the possibility of a considerable thickness is suggested.

Thin deposits of gravel usually under 2 feet in thickness are associated with the contact of the Cretaceous sediments and the Crystalline rocks. These deposits may be found scattered along the Fall Line, just north of the Central of Georgia Railway from a point just west of Howard, in Taylor County, to the western boundary near Box Spring. They have little commercial value but are suitable for road building and as concrete aggregate for local construction work. Outcrops and deposits of this gravel are especially prominent along the Columbus-Talbotton road, but all that were investigated showed less than a foot of gravel. Greater thicknesses, however, may occur in more remote places.

Most of the larger streams of upper Talbot County have deposits of good sand for concrete aggregate, produced from the weathering of the quartzite, schists and diorite. Those of the eastern part of the county, including Flint River, have probably larger and better deposits than elsewhere. None of this type of sand is produced for shipment.

TATTNALL COUNTY

No sand pits are operated in Tattnall County. The beds of Altamaha River, on the south, and Ohoopee River, on the east, as well as sand hills bordering Ohoopee River, west of Reidsville, afford almost unlimited sand deposits.

Ohoopee River.—Large bars on the inside of the numerous meanders of Ohoopee River, ranging from a few hundred square feet to half an acre in extent, occur along the river from its confluence with Altamaha River through most of the county. The sand is of pure white, medium- to coarse-grained quartz, with coarser material, and even a few pebbles, at the sharper curves. The bed of the stream and flood deposits along the banks are composed of whiter, but finer-grained sand. The sand is suitable for building purposes and some grades of bottle glass.

Sand-hill deposits.—Along the east side of Ohoopee River, from Battle Creek to the north line of the county, a remarkable area of pale yellow and gray sand occurs in a belt from one to four miles wide. The surface of the belt is level to gently rolling with included "bays" and undrained depressions and characteristic dunes of aeolian origin. The thickness of the sand ranges from 4 to 25 feet. At the surface it has been leached white by rain and organic acids, but it becomes pale yellow or gray at depths of from a few inches to a foot. The sand is medium-grained in texture, and in places gravelly, with little sign of stratification in the upper 5 to 8 feet at least. The present condition of the sand is probably due to wind action, but the lower part of the deposit was probably an ancient flood-plain deposit of Ohoopee River. Samples *T-27, T-31, T-32,* are very similar to the sand in this belt, and the results of their tests can be used in judging this sand. Most of it is suitable for brick mortar and plaster work only. Although tremendous deposits of the sand exist in the county, at only two points is there a possibility of present commercial exploitation. (1) West of the Georgia Coast & Piedmont Railroad at Reidsville, which place is on the edge of the belt and the thickness of the sand is probably considerably less than that part closer to the river. (2) The cuts of the Seaboard Air Line Railway, 4 miles west of Collins, do not expose more than a foot or two of sand, so that a spur at least half a mile long would be necessary to reach the belt to the south.

TAYLOR COUNTY

Much of Taylor County lying in the Coastal Plain is covered with a thick layer of current- and wind-worked residual sand which is commercially exploited in several large pits along the Atlanta, Birmingham & Atlantic Railway and the Central of Georgia Railway. Some gravel also occurs in the county near the Fall Line; these deposits although extensive are generally thin and suitable only for local road-building purposes.

W. C. Harkey Sand Company.—The W. C. Harkey Sand Company (postoffice, Mauk) owns 400 acres of sand land on the Atlanta, Birmingham & Atlantic Railway, a mile south of Norwich. The sand has been removed from over two acres, and the face of the pit ranges from 12 to 18 feet high and is about 800 feet long. The pit has been in operation since 1906. The sand is gray at the top, becoming yellow a few feet below the surface, but toward the bottom of the pit it gets paler and finally grades into a red sandy clay. No signs of stratification of the sand were noted, as is common in some other pits in the area. The sand is fine-grained, becoming medium-grained with a few particles up to $\frac{1}{8}$ inch in size in the lower third of the pit. Like all of the sand in this and adjoining counties, it is free from organic matter and has practically no clay, except in the upper foot or so where it is influenced somewhat by the soil and vegetation. Sample *T-76*, which is an average sample from the entire face, shows a fineness modulus of 1.49 and 46 per cent coarser than 48 mesh.

The freedom from signs of stratification noticed in this pit is somewhat peculiar to the sand on the eastern border of the sand-hill area extending across Middle Georgia. Marked stratification lines in the pits in the central and western parts of the belt point to the fact that those portions may represent the original water-deposited material, and the unstratified belt to the east may have originated later through the action of the wind.

Sand from the Harkey pits is shipped to Atlanta, Manchester, and other points on the Atlanta, Birmingham & Atlantic Railway; some has been shipped to Tate, Ga., for use in sawing marble.

In the vicinity of Norwich the sand appears to be very thick and extensive, and most of the land adjoining the railroad is held for its sand. Most of the wells show sand from 6 to 30 feet in thickness, and some show even greater amounts, although they generally encounter clay or kaolin strata of differing thicknesses. At a point a third of a mile east of the 227-mile post, 10 feet of sand shows in a cut through a small hill. A well 1,000 feet to the south showed 8 feet of sand. At the 227-mile post a maximum of 7 feet of gray sand is underlain by a coarse, reddish-yellow molding sand 2 to 3 feet thick and then by red clay. A small pit has been opened here in the sand, a few feet below the track, apparently for grading purposes.

Exposures of the red clay beneath the sand show its upper surface to be very undulating which adds some uncertainty in estimating the size of a sand deposit and also seems to emphasize the necessity of careful detailed testing with augers before passing final judgment on its extent, even though the surface indications may be very favorable.

Dry Ridge.—A small pit is operated by O. O. Brown, of Howard, a few hundred yards east of Dry Ridge on the Central of Georgia Railway, near the eastern edge of the sand belt. The face is from 12 to 15 feet high and about 700 feet long. The sand is stratified and presents a wavy, corrugated appearance from the bottom of the pit to within 5 feet of the top. The lower two feet of sand is fairly coarse, pale yellow, and of excellent quality. Below this a sandy clay occurs. Sample *T-89* represents the general character of this sand, and its examination shows a fineness modulus of 2.22 and 79 per cent of the sand coarser than 48 mesh. Two miles west of Butler on the Central of Georgia Railway considerable sand occurs. Mr. Brown has bought 200 acres near here and contemplates opening a sand pit.

Wall property.—Near the eastern border of the sand area along the Atlanta, Birmingham & Atlantic Railway, 1½ miles northwest of Mauk, H. S. Wall owns 16 acres of land underlain by gray to yellow sand. Holes dug with a post-hole digger showed at least 7 feet of fine- to medium-grained sand. Mr. Wall claims to have found a depth of 20 feet of sand on this property by boring with a soil auger. Sample *T-75*, from this deposit, has a fineness modulus of 1.64, and 58 per cent is coarser than 48 mesh.

Along the railroad 2½ miles southeast of Mauk, cuts show at least 5 feet of fine-grained sand for a distance of 1,000 feet. Since the land rises southward from the railroad it is possible that the sand reaches a thickness close enough to the railroad to be exploited commercially. Eastward from this point along the railroad, although occassional thin deposits of sand occur, nothing of commercial value is found.

GRAVEL DEPOSITS

Peeble.—On the Central of Georgia Railway at Peeble, 3 miles east of Butler, a small pit has been opened in a somewhat variable deposit of red quartz gravel.

Section in gravel pit at Peeble

	Feet
Quartz gravel with dark red clay	2
Red, clayey sand	1
Gravel, composed of quartz and granular quartzitic pebbles from ½ to 1 inch in size usually and bound with a dark red clay	6
Reddish yellow and red sand	6

The main gravel, as shown in the lower part of the cut, becomes thinner and breaks up into several streaks 150 feet further east. On the south side of the cut a smaller percentage of pebbles occur in the gravel. The pebbles exposed at the surface are easily broken, and some are even friable, but they are tougher a few feet below. The material appears to be well suited for road making and if washed can be used for concrete aggregate.

This deposit continues westward in the general direction of the railroad, and a quarter mile nearer Howard a 400-foot cut exposes a maximum of 4 feet of fairly coarse gravel in a red clay matrix with coarse clayey sand and clay lenses adjoining and merging irregularly into gravel lenses. The cover ranges from 2 to 5 feet and is clay and sand. The gravel appearing along the road may be traced in the fields north of the road. The pebbles are of granular quartz and range from ½ inch to 2½ inches in diameter. In general, the gravel in the vicinity of Peeble appears to be exceedingly irregular in extent and thickness, often thinning out entirely from one side of a railroad cut to the other, and for this reason a large commercial deposit probably does not occur.

A cut of the Central of Georgia Railway, 2½ miles west of Reynolds, shows from 3 to 5 feet of Cretaceous gravel in a clayey sand with white clay beneath. The deposit would make a good road material, but its extent is very irregular and uncertain.

Beechwood Station.—In a small abandoned pit at the side of a spur from the Central of Georgia Railway leading to the sawmill near Beechwood Station the following section was noted:

Section at Beechwood Station

	Feet
Fine clay gravel and sand; pebbles generally under half an inch in diameter	6
Coarse, clayey sand	6
Fine to medium-clay gravel, pebbles up to 1 inch	6
Clay and sand gravel with irregular sand lenses through it	6

Sample *T-73,* representative of this deposit, showed a clay content of 12 per cent and a fineness modulus of 4.76 with 75 per cent of the material coarser than 4 mesh and none of the pebbles coarser than 1 inch in diameter.

Along the main line of the railroad west of the station, several cuts show from 2 to 6 feet of clayey, fine-pebbled gravel. The outcrop extends for a quarter of a mile west of the station both above and below the railroad grade, and indications of gravel appear in the hill north of the railroad. The pebbles, in places, become much coarser, ranging up to 2 inches in diameter and generally sub-angular. A coarse, slightly clayey sand generally occurs with the gravel. A company formerly making bricks near here is said to have prospected in the vicinity for gravel and also in the bluffs overlooking Flint River 2½ miles below. These holes are filled up now and no data could be obtained from them.

Five Points.—The contact of the Lower Cretaceous and the Crystalline rocks occurs on the Carsonville road a half mile south of Five Points. Coarse gravel and clay are usually found just above the schists. A mile and a half south of Five Points, near the top of the hill, at least 2 feet of coarse gravel shows in the road cut and also covers the fields 10 feet above the outcrop, although no gravel appears in a well at the house at the top of the hill.

Gaultney property.—Near the junction of the Carsonville road and a branch road running east, considerable gravel appears in the road and fields. Cuts indicate several 2-foot streaks, although the well at the house, on the E. M. Gaultney property did not show reliable indications of more than a foot or two. Further east, George Greer's well shows 6 feet of coarse gravel, and several acres are covered with gravel nearby. This well is 7 feet higher than the

Gaultney well and about 25 feet higher than the first outcrop noted on the Carsonville road south of Five Points.

Gaultney property.—Gravel covers the fields over a considerable area on the M. T. Gaultney property and on the E. C. Perkins farm further east of the Carsonville road. Gravel, however, does not show up in large amounts in the wells in this vicinity. It is generally reported by well diggers that only from 1 to 2 feet are found close to the surface, and then about 10 to 15 feet below this another streak of the same thickness occurs. On the hill-side leading down to Patsiliga Creek several streaks of coarse granular quartz gravel from 2 to 2½ feet thick outcrop, usually separated by 8 or 10 feet of clay.

Flint River.—West of the river the second bottom is underlain by at least 3 feet of coarse, white, tough quartz sand and gravel. The material outcrops on the Wire road (Roberta-Reynolds road) 250 feet west of the bridge and at the road forks, a quarter of a mile beyond on the C. H. Neisler plantation, 13 feet of clay was penetrated before reaching 2½ feet of quartz gravel, in which the well was stopped.

The second series of gravel deposits begin 30 to 35 feet vertically above the first and outcrop on the "Wire" road where 5 feet of excellent, coarse, clay gravel can be seen in the road cut on the face of the second river terrace. Below this, 5 feet of poorer clayey gravel occurs. This deposit is much older than that on the second bottom below and is probably of Satilla age. A well at a negro tenant's house on the Neisler plantation, at the top of the hill, 300 feet west of the outcrop, is said to have penetrated 5 feet of clay and then 10 feet of gravel. The upper half is of very good quality, the pebbles constituting about 60 per cent of the entire mass.

On the "Wire" road, 4 miles west of the river, a 4-foot bed of coarse-pebbled sandy gravel outcrops along the road for a few hundred feet. Sample *T-71,* from this locality, shows 95 per cent of the material to be coarser than 4 mesh and the balance clay. The pebbles are coarse and of quartz or fine-grained quartzite, and fairly tough.

Neisler property.—About 3 feet of good sandy gravel shows at the cross roads on the J. H. Neisler property on the Reynolds-Fickling Mill road 6¼ miles northwest of Reynolds. The pebbles are of fairly durable quartz and quartzite from ½ to 2 inches in diameter mostly. The gravel appears to cover most of the small hills to the north and occurs on both sides of the branch. Only 2 feet showed in a well just west of the cross roads.

On the same road 3½ miles northwest of Reynolds, near a small branch from 2 to 3 feet of clay gravel with coarse sand lenses outcrop along the road. The material appears to extend 800 feet east of the road into the fields and is used for road purposes. Sample *T-72*, from this locality, and typical of the Fall Line gravels in Taylor County, has a fineness modulus of 6.50 and 74 per cent coarser than 4 mesh.

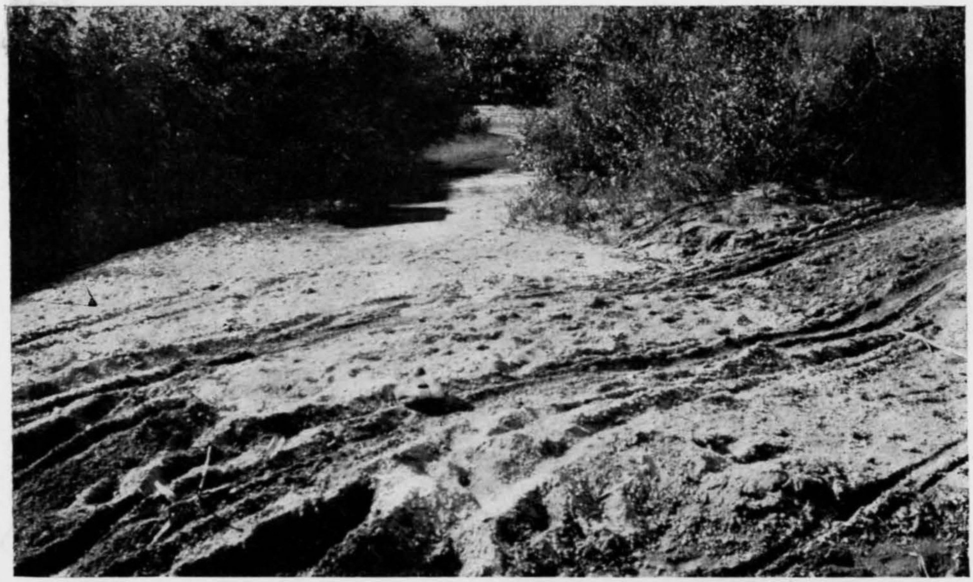
A mile and a quarter northwest of Reynolds on the Fickling Mill road 2 to 3 feet of gravel outcrops having sub-angular, tough, quartz and quartzite pebbles ranging from 1 to 2 inches in size. West of the road, on the John Musselwhite property, 5 feet of gravel appears in a gully on the hill-side. The well at the house shows 10 feet of yellow sand beneath 4 feet of good gravel. A small pit for road gravel has been opened along the road. East of the road on the J. Hill property, gravel caps the hills from a third to a quarter mile from the road. A good concrete sand deposit covering from 10 to 15 acres occurs on the Hill property near the road apparently 8 to 10 feet thick.

Reynolds-Macon Highway.—Three miles from Reynolds 3 to 4 feet of quartz gravel, whose pebbles range from 1 to 2 inches and having a sandy clay matrix may be seen in the road cut and in the fields on either side. Although gravel occurs in a well 17 feet below the surface 700 feet west of the road, the cover is too thick. East of the road along the branch the gravel may be utilized, however.

A small sand pit has been opened along the road 4½ miles north of Reynolds showing 5 feet of coarse (¼ inch and smaller) sand used in road construction and for other purposes. The sand is of excellent quality, and the deposit appears to cover several acres on either side of the road.

Four miles north of Reynolds, at the F. M. Griffith place, 2 feet of white quartz gravel outcrops in the road, and a 4-foot bed appears in a well at the house 14 feet below the surface. At Lockett the same bed persists, and in wells along the road from 2 to 5 feet of white gravel are found.

Regarding the numerous indications of gravel in Taylor County, with the possible exception of that near Beechwood, it may be said that none of those examined by the writer warranted extensive commercial development on account of their distance from transportation and their small thickness and irregularity. They should serve as excellent local sources for road building material, and it is possible



A. SMALL SAND AND GRAVEL DEPOSIT, MOUNTAIN CREEK, NEAR ALTO, BANKS COUNTY

B. SAND AND GRAVEL DEPOSIT, PROCTER CREEK, 3 MILES SOUTH OF ACWORTH ON MARIETTA ROAD, COBB COUNTY that using them as a guide, more detailed prospecting may lead to the discovery of commercial deposits close to railroads. The most favorable place for the accumulation of such deposits should be east of the intersection of Flint River and the Fall Line, but even in that vicinity no large, extensive deposits were noted.

TELFAIR COUNTY

Surficial sand from one to two feet thick covers a considerable part of Telfair County, particularly near the streams; and beneath it the mottled, feldspathic sands and clays of the Altamaha formation are found. Commercial sand is produced along Little Ocmulgee River above Lumber City.

Lumber City Sand and Concrete Company.—On the Southern Railway, about 2 miles northwest of Lumber City, a pit has been opened on the property of J. T. Wilbanks, lot 223, and a very good quality of concrete sand is shipped to almost every part of the state. (Plate XV-A.)

Section at pit of Lumber City Sand and Concrete Company, Lumber City

	Feet
Soil	2
Fine sand to clayey sand	2–4
Coarse sand, with pebbles up to ¾ inch. The coarser sand is in lenses which predominate and are separated by streaks of fine-grained, clayey sand. Cross-bedding of the coarser sand is prominent	6–10

The pit covers a little less than an acre and is situated 15 feet above Little Ocmulgee River (Gum Swamp Creek), and the bed of the pit is about the same distance below the Southern Railway grade. A spur 300 feet long leads down into the pit which is quite free from water.

The sand from this pit is of high quality and excellently suited for concrete purposes. Sample *T-15 A*, representative of the sand, has a fineness modulus of 2.64 and 78 per cent is retained on 48 mesh. The coarse grains are mostly of clean, well-rounded or sub-angular quartz and probably 5 per cent feldspar; a little ilmenite occurs in fine grains. The color is yellowish-white to pale yellow. Practically no organic matter occurs in the sand. Compressive strength tests made of this sand for the Moultrie Construction Company at the Georgia School of Technology showed a strength of 2,950 pounds per square inch at the end of 7 days, or 110 per cent of normal.

Within the bed of Little Ocmulgee River, near this pit, are large deposits of excellent gravel capable of yielding probably hundreds of carloads and which could be obtained with little difficulty. Near the curves in this stream above and below this point similar gravel is abundant.

Walker property.—A gravel deposit occurs on the property of H. G. Walker, less than a quarter of a mile west of the house and the Lumber City-Towns road, and about 2½ miles west of Lumber City. An area of between 2 and 3 acres shows a sandy gravel composed of rounded and sub-angular tough quartz pebbles, ranging from ¼ to 1 inch in size. The fineness modulus, as determined from sample *T-208,* is 5.72. The deposit lies about 25 feet above and a little to the south of a small branch. A small pit shows the deposit near it to be from 2 to 2½ feet thick and underlain by yellowish-red clay. The gravel was formerly screened in a rotary screen through ¼-inch mesh and hauled to Lumber City and other points. The workable gravel is restricted to about an acre and a half. The deposit is a little less than a mile south of the Southern Railway.

Ocmulgee River.—The bars and bed of Ocmulgee River, which forms the southern boundary of the county, have inexhaustible deposits of excellent sand for concrete purposes. The bars occur on the points of the river curves and usually are half an acre or less in extent. The remoteness of all of these deposits from rail transportation, except at the Southern Railway crossing east of Lumber City, will require the use of boats or barges in case any of the river sand is exploited commercially.

Sample *T-207,* obtained from the bed of the river at Lampkin's Old Field Ferry a short distance from China Hill, in the extreme southern part of the county, shows a fineness modulus of 3.15 and practically none of it finer than 48 mesh. The color value of the organic matter is 50. The sand is mostly angular, iron-stained quartz and some mica, feldspar, and ilmenite, and is typical of the river deposits.

Other deposits.—Along Sugar Creek, particularly where the Lumber City-Towns road crosses it, a thick deposit of white, medium-grained sand is found, averaging 10 to 12 feet in thickness. The deposit is particularly heavy on the southeast side of the creek and forms low sand hills, with sharp scarps in places, overlooking the creek.

TERRELL COUNTY

The surface of Terrell County consists principally of red clay or sandy clay, and deposits of any kind of sand are small, or of poor quality, and restricted to the sides and beds of the larger streams.

Sasser.—Two and a half miles southeast of Sasser, surficial, fine-grained sand occurs in somewhat extensive beds, but only from two to three feet thick. The sand is suitable for local road use.

Brantley Creek.—East of Brantley Creek, on the Sasser-Herod road, about seven miles from Dawson, ten feet of red sandy clay overlie at least six feet of fine-grained white sand, sufficiently pure for glass purposes, but at present of no value except for local uses, due to its inaccessibility and the thick overburden. It is possible that a search along this and other creeks in the county may disclose deposits of white sand with less overburden and nearer a railroad.

Ichawaynochaway Creek.—Yellow, medium-grained sand, of Eocene age, underlies red clay and red sandy clay east of Ichawaynochaway Creek. Due to a thick overburden of from 8 to 12 feet the sand at this point is of no commercial value, but is used for local purposes. It is probable, however, that at other places, where this or other streams have worn down to the level of the coarse sand, good deposits may be found. The most suitable places to search for such sand would be on the slopes of the larger stream valleys.

In the northwest part of the county, along both sides of Ichawaynochaway and Turkey creeks, extending south from Macedonia Church for about 3 miles, surficial deposits of very pale yellow, fine-grained sand occurs. The largest deposit lies about half a mile southeast of Macedonia Church on the west side of Turkey Creek. These deposits are usually less than 5 feet thick, and their distance from rail transportation prevents their utilization for any but local purposes.

Parrott.—In the vicinity of Parrott, in the northwest part of the county, some medium-grained sand occurs. A sample of that from the B. F. Morgan property was a pale orange and composed of uniform, medium-grained quartz. The deposit covers several acres and is said to be over 7 feet thick.

THOMAS COUNTY

Light sandy clay, or sand, covers most of Thomas County, but is underlain at depths of from a few inches to several feet by clay and clayey sand.

Thomasville.—No large sand deposits occur close to Thomasville. Sand for local use is hauled from the east side of Ocklocknee River on the Cairo road, 4½ miles west of Thomasville where a small pit shows the following section:

Section of pit, 4½ miles west of Thomasville, on the Cairo road

	Feet
Soil and loamy sand	2
Fine, gray, silty sand	3
Coarse, clayey sand containing strata of reddish-brown, sandy clay 1 to 2 inches thick and occurring every 4 or 5 inches	4

The strata in the lower part of the pit are wavy indicating a probable fluviatile origin of the sand. The belt, of which this deposit forms a part, ranges from 300 to 1,500 feet in width and extends along Ocklocknee River throughout the county. It is not, however, confined to the east side of the river, as is so universally general in South Georgia, but is more generally found on the west side of Ocklocknee River and on both sides of Little Ocklocknee River, and to a lesser extent along Barnett Creek, which forms the western boundary of the county. In general, sand of this type is from 8 to 15 feet thick, gradually decreasing in thickness further from the river, and having a rather large proportion of clay.

Ocklocknee River.—Beautiful, clean, white sand, from fine- to coarse-grained, occurs in bars from an eighth of an acre to an acre in extent in the bed of Ocklocknee River throughout most of its course in the county. Sand was formerly pumped from the river bed to railroad cars at the Atlantic Coast Line Railroad crossing. The railroad bridge here is about 25 feet above the stream, so that considerable power would be required to raise the sand.

Sand from a half-acre bar has been successfully used in the construction of the bridge over the river on the Thomasville-Meigs road. (Plate XIV-B.) Sample *T-214*, from this deposit, shows a fineness modulus of 2.06 and 75 per cent coarser than 48 mesh. The organic matter color value is 125. Tensile strength tests of mortar made from this sand, obtained in the river bed 400 feet north of the bridge on the Meigs road, by the Pittsburg Testing Laboratory for Thomas County, showed 135 per cent of that made from normal sand in 7 days, and 115 per cent of normal in 28 days.

The river sand has the peculiar quality of "singing" or "whistling" when walked over, especially if the heels are dragged or shuffled. Similar sands were noted along Allapaha River, in Echols County, and on Canoochee River, west of Groveland, by R. M. Harper.[1]

Williams pit.—Sand, one mile west of Ocklocknee River, on the land owned by Homer Williams, is mined by J. W. Dillon, of Thomasville. (Plate XIV-A.) The pit covers about 2½ acres, and considerable sand is shipped to Waycross, Bainbridge, and other points in South Georgia. The pit contains strata of good, clean, coarse sand near the bottom, but the sand in the upper part is somewhat silty and has a large clay content. The section is as follows:

Section of Williams pit, one mile west of Ocklocknee River

	Feet
Sandy and silty, dark gray soil	1–2
Yellow, silty sand used for plaster mortar	5–6
Coarse- to medium-grained, clayey sand with streaks of brown clay or sandy clay, 1 to 3 inches thick every 4 to 6 inches. Pebbles up to $\frac{3}{16}$ inch occur through it, becoming more numerous toward the bottom	5
Coarse, gritty quartz sand, pebbles up to ¼ inch, some ⅜ and ½ inch, and a few 1 inch in diameter, mostly angular. Red and brown clayey strata occur. Streaks of white, medium-grained sand. Water level at bottom of this streak	4

The sand is shoveled into wheelbarrows which are wheeled to the car. The men are paid so much a ton, and one man is frequently able to load an entire car of 30 to 35 tons in a day.

Sample T-217 represents the general character of the sand from 6 to 12 feet below the surface. This sample has a fineness modulus of 2.18, and 68 per cent is coarser than 48 mesh. It contains only a trace of organic matter. Tensile strength tests of mortar made from this sand by the Pittsburg Testing Laboratory, and furnished by Mr. Frank Mitchell, showed a strength of 112 and 99 per cent at 7 and 28 days, respectively.

North of the railroad 4 feet of sand similar to that on the south side is exposed in the cut for several hundred yards. This land is owned by W. B. Devley. The deposit in which this pit is located extends along the west side of Ocklocknee River in a belt 1,000 to 2,000 feet wide beginning about 1,000 feet back from the river, from the vicinity of Chastain, in the northern part of the county, to Pine Branch, about 2 miles below the Thomasville-Meigs road.

1 Personal communication.

North of the Thomasville-Meigs road, 400 yards west of Ocklocknee River, a small pit has been opened and shows 6 feet of fine-grained sand, similar to the sand in the upper part of the Williams pit, indicating the extension of the deposit southward along the river.

The white sand in bars, and in the bed of Ocklocknee River, is sufficiently pure for the manufacture of glass, but it would be rather difficult to get it to a railroad except that near the Atlantic Coast Line crossings, northwest and west of Thomasville. The most extensive deposit of white sand occurs beneath the upper railroad crossing (Albany branch). The stream bed is almost a quarter of a mile wide here at low water and is covered with small dunes of fine-grained sand (*T-216*) of dazzling whiteness. In the present stream channel the sand is somewhat coarser (*T-214*) but almost as white as that in the bars. An analysis of this sand gave the following results:

Analysis of sand from Ocklocknee River bed, southwest of Williams Station, Thomas County, T-214

Ferric oxide (Fe_2O_3)	0.60
Silica (SiO_2)	99.40

White sand bars continue, with interruptions, down the river to Pine Park wagon bridge, two miles below the crossing of the Atlantic Coast Line Railroad running to Bainbridge. At the lower bridge the river is 35 feet wide and from 1 to 3 feet in depth (low water) and has a moderately rapid rate of flow. The sand in the river bed and in the bars ranges from 2 to 5 feet in depth occupying bars from an eighth of an acre to an acre in extent and is underlain by blue clay and sandy clay.

West of the river just north of Pine Park bridge, a fine-grained yellow and white stratified sand, 10 feet thick, occurs.

TIFT COUNTY

The surface of Tift County consists of a light, clayey sand with numerous iron oxide pebbles. Clays and clayey sand, having some pebbly layers, underlie the surface to a depth of 75 or 80 feet, and beneath these the Alum Bluff formation occurs.

Tifton.—Little sand of value, even for local purposes is found near Tifton. A small pit is worked on the Unionville road, one mile south of Tifton, but the sand here is fine-grained and loamy.

Little River.—The usual fluvial sand hills parallel the course of Little River through the county and range from 500 feet to a mile in width. The belt is widest just north of the Atlantic Coast Line Railroad crossing, 3 miles west of Tifton, and to the north of Five Bridges. The topography of the belt at this point is gently rolling with some undrained depressions in it. Two cuts on the railroad about 900 feet apart show about 10 feet of yellowish, fine-grained, clean sand, each having a length of 300 feet. The sand appears to thicken to the north, and the average depth over 300 or 400 acres would be about 8 to 10 feet. The most suitable place for a spur is 1 mile back from the railroad trestle, although the thickness of the sand would probably limit its operation to hand labor. The sand is somewhat poorer than that on Seventeenmile Creek near Douglas (see *T-234*, p. 179).

At the Atlanta, Birmingham & Atlantic Railway crossing of Little River near Overstreet bridge, 5½ miles west of Tifton, a cut shows 600 feet of fine-grained, loamy sand, 10 feet thick. The sides of the cut support vegetation and the sand is of poor quality, although suitable for unimportant plaster or brick mortar work or for sand-clay roads.

The Bureau of Soils gives the following mechanical analyses of the general type of sand[1] occurring along the streams:

Mechanical analyses of sand-hill

Number	Description	Fine gravel	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt	Clay
20367	Soil	1.0	20.4	28.4	38.9	6.0	3.3	2.0
20368	Subsoil	1.5	21.6	27.0	39.5	5.5	2.4	2.8

A few isolated areas of coarse, light gray to white quartz sand with 12 to 15 per cent silt and clay occur in the county, capping relatively high ridges or hills to a depth of 3 or 4 feet. One area occurs on the Georgia Southern & Florida Railway (Ashburn-Tifton road) 4 miles north of Tifton and a smaller area is found 1½ miles southeast of this on the Zion Hill church road.

1 Soil Survey of Tift County, Ga., U. S. Dept. Agr., p. 16, 1910.

TOOMBS COUNTY

Much sand occurs east of Pendleton Creek in Toombs County, but no sand or gravel has been commercially exploited.

Lyons.—A small branch in the western part of the town has sufficient sand of fairly good quality for local uses. East of Lyons, where the Central of Georgia Railway crosses Pendleton Creek, a belt of sand is favorably situated for transportation just east of the creek. The cut shows 6 feet of fine- to medium-grained, gray to yellow sand for about 700 feet. This sand belt continues east of Pendleton Creek for practically its entire course through the county. It is especially prominent where the Lyons-Cobbtown and Lyons-Collins roads cross it.

Vidalia.—Sand for use in Vidalia is obtained from the north side of Swift Creek on the Soperton road, 2 miles from town. The sand is from 4 to 8 feet deep over a half acre here, and is fine-grained and yellow. Sample *T-266* has a fineness modulus of 1.29 and 38 per cent coarser than 48 mesh.

A number of thin gravel deposits, rarely more than a foot thick and usually of small extent, occur in the county, but their commercial utilization is not possible at the present time.

TREUTLEN COUNTY

No sand or gravel deposits of commercial value occur in Treutlen County, although plenty of sand for local use is found.

Soperton.—Most of the local sand supply of Soperton is obtained from a small deposit of fine-grained sand, 1 mile north of the town on the Norristown road. On this road, 2 miles north of Soperton, is a small deposit of much better sand, along and in a branch 300 feet south of the old tram-road crossing, between the public road and the tram-road.

East of Red Bluff Creek, 3½ miles from Soperton on the Dublin road, is a narrow belt of fine-grained sand.

Oconee River, forming the southwest boundary of the county, has large quantities of excellent medium- and coarse-grained sand that has been successfully used at Dublin and Mt. Vernon.

Thin deposits of gravel and coarse sand are scattered throughout the county generally at the top of small hills, but their thickness rarely exceeds a foot, and their extent is small.

TURNER COUNTY

The surface of Turner County is sandy, but is underlain by clay at slight depths, and by limestone and clays of the Alum Bluff, Chattahoochee, and Ocala formations in turn, at greater depths.

Very little sand of even slight commercial value occurs in the county. Most of the sand used in the towns is shipped in or obtained from small local accumulation along the roads, which is usually of inferior quality. Northeast of Deep Creek, 5 miles east of Ashburn at Geoghagan bridge on the Rebecca road, an area of medium-grained, gray sand about 5 feet thick was noted. It apparently is part of a more or less continuous belt paralleling the creek from the vicinity of Worth to its confluence with Allapaha River. Sand of this character occurs east of Little River and Daniel Creek in interrupted strips from 500 to 800 feet wide, and also in isolated areas of a few acres, especially in the western part of the county. Due to a higher loam content, this sand is usually somewhat inferior to that east of Allapaha River, which partly bounds the county on the east.

TWIGGS COUNTY

No commercial sand or gravel is produced in Twiggs County.

Big Sandy Creek.—Considerable coarse, gray sand, well suited for concrete purposes, occurs along Big Sandy Creek in the northern part of the county, both in the bed and on the banks a few hundred feet back from the stream.

Throughout most of the county the hills are capped with a bright red, clayey sand ranging from 5 to 50 feet thick and forming part of the Claiborne group. In a gulley on the McCrary property, 2 miles northeast of Jeffersonville, 8 to 10 feet of the red sand overlies 10 feet of yellow, medium-grained quartz sand. Similar occurrences of sand are frequent in the county, but its value is small due to lack of transportation for most of it, and the heavy cover of clayey sand which generally overlies it. Along the streams, however, this sand may be exposed at points convenient for extensive mining or at least for use in road building or in concrete work.

WARE COUNTY

No sand is produced in Ware County for shipment, although large deposits occur in the bed of Satilla River and along Seventeenmile Creek. Local supplies for Waycross generally come from the deposits in Pierce County, north of Satilla River.

Satilla River.—In the bed of Satilla River along most of its course in Ware County, and particularly along that part of it northeast of Waycross, which forms a boundary of the county, white, medium- to coarse-grained sand, suitable for either concrete or the poorer grades of glass, occurs. The Atlantic Coast Line Railroad crosses the river 2½ miles northeast of Waycross. The sand in the river bars, which are usually along the right bank, is somewhat finer-grained than the sand in the river channel proper. The main difficulty in recovering the sand would be in raising it from the river to the railroad, a distance of 25 feet. Unless the demand was large and steady, it is doubtful whether it would pay to install the necessary equipment to properly recover the sand.

Analysis of sand from bed of Satilla River at Atlantic Coast Line Railroad bridge, northeast of Waycross

Moisture at 100° C	0.04
Loss on ignition	0.35
Lime (CaO)	0.00
Magnesia (MgO)	0.06
Alumina (Al_2O_3)	0.51
Ferric oxide (Fe_2O_3)	0.72
Titanium dioxide (TiO_2)	trace
Silica (SiO_2)	97.91

Sand-hill deposits occur on both sides of Satilla River, westward from Waltertown to the Coffee County line. The sand is medium-grained, yellow and has practically no clay. It ranges in thickness from 10 to 20 feet, and continuous areas of several hundred acres are common. The most extensive deposit lies just northwest of Waltertown south of the river and extends westward for 2½ miles. The railroad approaches to within half a mile of the eastern end of the deposit. North of the river, opposite the deposit just mentioned, a less extensive deposit occurs, but more favorably situated with respect to the railroad. This deposit was formerly worked just over the line to the east, in Pierce County. Southwest of the river along the Atlantic Coast Line Railroad and 1½ miles northeast of Waycross, a small deposit of fine-grained, yellow sand occurs.

Other deposits.—Large deposits of yellow sand of the fluvial hill type also occur east of Seventeenmile Creek from the Coffee County line to its junction with Satilla River; and east of Hog Creek, in the northwest part of the county, and Little Hurricane Creek in the northeast part of the county. Distance from transportation will prevent the utilization of these deposits for some time.

WASHINGTON COUNTY

Surficial gray sands and variegated sandy clays and sands of the Altamaha formation cover most of Washington County. No commercial deposits of sand or gravel are exploited in the county, nor are there any deposits of either material of any size conveniently suited with respect to transportation.

On the Augusta Southern Railroad, just south of Warthen, 4 feet of fine-grained loamy sand occurs; and four miles beyond, similar sand, of little value and not over 5 feet thick, occurs.

Big Buffalo Creek in the western part of the county, especially just south of the Linton-Sandersville road, has bars of more than 1,000 square feet of brown, coarse-grained sand. This sand contains from 10 to 15 per cent of feldspar, limonite, schist fragments, and some gravel, but it is well suited for concrete aggregate.

Gray to white, fine-grained sand occupies large areas along the Linton-Deepstep road near Harmony Church, Pleasant Grove school and a few miles to the south. The sand is apparently part of the Fall Line belt so prominent in Crawford and Taylor counties and reaches a depth of from 3 to 10 feet in places.

Sand of fair quality is found in the beds of Ogeechee, Ohoopee, and Oconee rivers, but its recovery is out of the question at this time.

WAYNE COUNTY

The southeast part of Wayne County is covered with sand and underlain at depths of from a few inches to several feet by clay and clayey sands, and the rest of the county consists of the usual surficial sands and variegated clays of the Altamaha formation. No commercial sand pits are operated in the county. Aside from the surficial deposits which are almost universal, Altamaha River, bordering the county on the northeast, and Satilla River on the southeast, afford the best potential sources of sand.

Satilla River.—Bars of white, medium-grained sand, ranging from an eighth acre to an acre in extent occur in Satilla River. The bars are prominent near the bridge on the Waycross-(Lulaton) Brunswick road, 2 miles east of Lulaton. On either bank, similar sand, but somewhat finer, from 8 to 15 feet thick, occurs. Sand hills of considerable extent, but of much less prominence than in Ware and Douglas counties, are also found on both sides of the river at this point, particularly on the east side. Proximity to the Atlantic Coast Line Railroad renders the commercial development of this sand possible.

Altamaha River.—Gray and yellow surficial and residual sand ranging from 2 to 10 feet in thickness borders Altamaha River in Wayne County, particularly east of Jessup, where access to them from the Atlantic Coast Line Railroad may be had. Deposits also occur near Mount Pleasant, on the Southern Railway. In the southern part of the county, heavy beds of gray, fine-grained sand are found near Waynesville on the Atlantic Coast Line Railroad.

WEBSTER COUNTY

The topography of most of Webster County is hilly and broken except for a few level areas between the larger streams. The Providence sand member of the Ripley formation is exposed in the extreme northwest part of the county and should afford supplies of fairly good sand were transportation closer. Residual sands and clays generally cover most of the surface, although no commercial sand is produced in the county. A number of areas in the county are underlain by coarse sand derived from the sand lenses in the Midway and Wilcox formations, and these are sometimes well exposed in gullies. Although the sand is generally of fair quality, the cover, consisting usually of red, clayey sand, is usually considerable, and will prevent extensive development of the deposits.

WHEELER COUNTY

The surface of Wheeler County is usually covered with sand from a few inches to several feet in depth. The mottled sands and clays of the Altamaha formation are exposed frequently beneath the gray surficial sands, and along the larger streams, exposures of sandstone of Alum Bluff age occur. The county is abundantly supplied with commercial glass and building sand along Little Ocmulgee River opposite Lumber City and at other points.

Darcy property.—About 4 miles northeast of Alamo, and a mile and a half north of the Seaboard Air Line Railway, a deposit of good gravel, about 15 acres in extent, occurs capping a small hill. The deposit was worked in 1916-1917 by Mr. Kennedy, and about 10 carloads of gravel were shipped to Alamo over a tram-road constructed from the pit to the Seaboard Air Line Railway for use in building the Wheeler County courthouse. The deposit has been well prospected with many pits, and most of them show a good thickness of clayey sand gravel, composed of rounded and sub-angular quartz pebbles, from ¼ to 4 inches in diameter, 16 per cent of which exceeds 1¼ inches in size. The gravel contains about 20 per cent sand and 5 per cent clay.

General section of gravel deposit northeast of Alamo

	Feet
Sand and sandy clay	1–2
Sandy gravel	2
Sand and sandy gravel	1–2
Sandy clay gravel	3–6

The pebbles are tough and do not show any signs of decay. The gravel in the pits generally stands unsupported and is yellow to yellowish-brown. Water is encountered at about 12 feet beneath the surface. The western part of the deposit becomes very clayey, and the marginal pits show an increase of clay and a decrease in the thickness of the gravel. A small frame building stands near the deposit, and parts of screening equipment may be seen nearby. The tram grade is still in fairly good condition, but the steel has been taken up and most of the ties have rotted.

Little Ocmulgee River (Gum Swamp Creek).—Exceptionally large deposits of sand occur north of Little Ocmulgee River, from 100 to 1,000 feet back from the stream, and extend almost without interruption across the county. The most prominent deposit is found along the Seaboard Air Line Railway, 2 miles east of Helena and a quarter mile east of the Alamo-McRae road. The sand here is pale yellow, of a medium-grained texture and ranges from 5 to 30 feet thick, over a distance of 1,200 feet along the track. The sand has been used to make a fill across the river swamp, and the face of the cut is about 300 feet northwest of the track. The deposit slopes southward to the river, so that southeast of the track the cut is only 6 feet deep and 100 feet long; on the opposite side, however, it probably maintains the thickness seen at the cut for at least 1,000 feet back from the railroad and parallel to Little Ocmulgee River. It was impossible to get a detailed section of the deposit as the material that had fallen from above concealed the natural face. Probably 2 feet of sandy soil caps the clean yellow sand. At the bottom of the deposit small pits reveal a white, medium-grained sand probably less than 4 feet in thickness. Springs issue from this level indicating the proximity of the underlying yellow clay. The deposit is one of the best examples of the aeolo-fluvial deposits so characteristic of the north and east sides of the larger streams of the coastal plain of Georgia.

Along Little Ocmulgee River, from the Seaboard Air Line crossing, almost to its confluence with Ocmulgee River at the southeast corner of the county, the sand is of small thickness, probably averaging 5 to 10 feet, but opposite Lumber City and about a mile west of Ocmulgee River, the existence of a thicker and larger deposit of sand has been established by extensive pits.

Hinson Sand Mines.—The property of the Hinson Sand Mines lies along Little Ocmulgee River eastward from the Alamo-Lumber City road and includes lots 370 and 371. (Plate XV-B.)

The pit has been operated since before 1900, having been opened by L. F. Hinson, and at present is carried on by Mrs. A. H. Mobley, of Lumber City. The deposit is reached by a standard gage spur from the Southern Railway at Lumber City, about 2,500 feet in length The sand is shipped principally to Chattanooga, Tenn., and to Tallapoosa, Ga., for use in the manufacture of soft-drink bottles. The topography of the deposit is gently rolling, and the surface is covered with a growth of scrub oak. The deposit occupies a ridge or terrace paralleling the river and from 25 to 30 feet above it. It is believed to represent the Satilla formation and is probably an ancient stream deposit.

Section at Hinson Sand Mines, Lumber City

	Feet
Sandy, gray soil	1–2
Yellow, fine-grained sand	2–4
Medium-grained, yellow to yellowish-white sand	1–2
White, clean, glass sand	6–9
Yellow, sandy clay	7

The glass sand grades sharply into the yellow sand above and is firmer than the yellow material, as it stands unsupported in faces 8 feet high, although the sand above quickly slumps down. The white sand is usually massive with little indication of stratification and no cross bedding. Fulgurites, or lightning tubes, produced by fusion of the sand by lightning, have been found in the white sand at least 12 feet below the surface.

Due to the occurrence of patches of inferior sand, the deposit is worked by hand, since a steam shovel would not permit a proper selection to be made. The upper cover is first removed by loading the sand in wheelbarrows and depositing it either in the previously worked-out portion of the pit, or loading it on cars and shipping it for building and locomotive purposes. This leaves a bench of white sand from which cars are loaded for shipment to the glass factories. The present pit is about 200 feet wide at the face and extends southeastward over 1,500 feet almost to Little Ocmulgee River. The glass sand deposit on this property appears to be very extensive as prospect pits and auger borings have shown it at practically every place they have been made.

Analyses of glass sand from Hinson Sand Mines, Lumber City

Constituents	*T-14*	*T-16*	*T-17*	*T-18*	*1113*
Moisture at 100° C	0.07	0.01	0.02	0.02	----------
Loss on ignition	0.14	0.30	0.24	0.29	0.56
Lime (CaO)	0.22	0.00	trace	0.00 }	1.85
Magnesia (MgO)	0.11	0.03	0.30	0.08 }	
Alumina (Al_2O_3)	0.31	0.58	0.96	1.59	
Ferric oxide (Fe_2O_3)	0.61	0.72	0.48	0.64	0.14
Titanium dioxide (TiO_2)	0.14	0.18	0.18	0.18	trace
Silica (SiO_2)	98.26	98.03	97.36	97.34	97.45
Total	99.96	99.85	99.54	100.14	100.00

T-14.—West side of pit face.
T-16.—North bank of Little Ocmulgee River near railway trestle.
T-17.—East side of pit face.
T-18.—Center of pit face.
1113.—Sample sent in by L. F. Hinson in 1909.

Sample *T-18*, representing the glass sand, has a fineness modulus of 1.83 and 65 per cent coarser than 48 mesh. The organic color factor is 50.

McLeod property.—West of the Lumber City-Alamo road and the Hinson property, somewhat similar sand apparently an extension of that on the Hinson property is found on the property of J. D. McLeod and brother. This deposit was worked prior to 1905, and considerable sand removed, but when visited by the writer in 1919 it was not in operation.

Analyses of glass sand from McLeod property, near Lumber City

Constituents	*T-21*	*T-25*
Moisture at 100° C	0.03	0.01
Loss on ignition	0.12	0.12
Lime (CaO)	0.00	0.03
Magnesia (MgO)	0.16	0.00
Alumina (Al_2O_3)	0.44	0.47
Ferric oxide (Fe_2O_3)	0.56	0.48
Titanium dioxide (TiO_2)	0.14	0.36
Silica (SiO_2)	98.38	98.34
Total	99.83	99.81

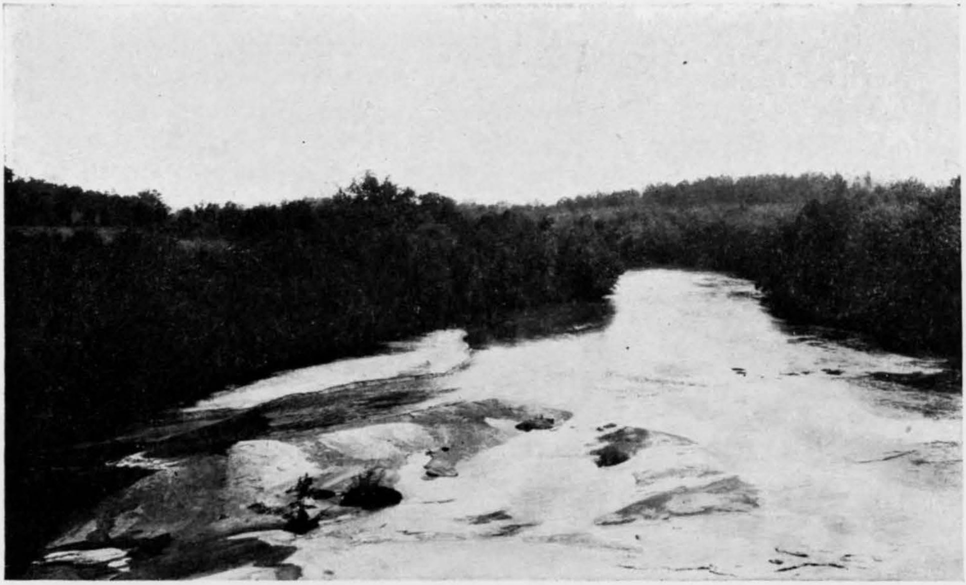
T-21.—General sample obtained from the collapsed face at the north end of the pit.
T-25.—Sample from the upper part of the glass sand at the south end of the old pit. Not a representative sample.

The deposit is covered with yellow and pale yellow sand, from 3 to 10 feet thick, which apparently becomes thicker as the river is approached. Due to the faces of the pit having caved in, it was impossible to obtain a section of the material or to measure the thickness of the glass sand, but Mr. McLeod reports that the thickness ranges from 5 to 10 feet. A mechanical analysis of *T-21* shows a fineness modulus of 1.95 and 71 per cent coarser than the 48-mesh sieve. The organic color value is 60.

The operations to date have not limited the extent of the glass sand deposits in this vicinity, and it is reasonable to believe that should the demand warrant it, further prospecting along Little Ocmulgee River, on the Satilla or upper terrace, will produce good results, although the quality of the sand is likely to differ considerably over short distances.

Alligator Creek.—A sand belt from 200 to 600 feet wide parallels the north side of Alligator Creek along most of its course. The most suitable place in case of development would be at the Seaboard Air Line Railway crossing, 1 mile south of Alamo. Cuts on the Alamo-McRae road north of the creek expose 2 to 3 feet of pure white sand, suitable for glass, beneath a heavy cover of yellow sand, but its total thickness and extent is unknown.

Ochwalkee Creek.—East of Ochwalkee Creek, along the Glenwood-Mount Vernon road, a deposit of sand of the sand-hill type



A. SAND BARS IN BROAD RIVER ABOVE STEEL BRIDGE ON ELBERTON-BERKELY ROAD, 10 MILES SOUTHWEST OF ELBERTON, ELBERT COUNTY

B. MOLDING SAND PIT, YELLOW RIVER MOLDING SAND COMPANY, 1 MILE EAST OF ALMON ON THE COVINGTON ROAD, NEWTON COUNTY occurs. The sand extends, with interruptions, practically from the Laurens County line to Oconee River and is cut by the Seaboard Air Line Railway. On the Mt. Vernon road it is from 5 to 15 feet thick over a distance of 800 feet. The sand is pale yellow to buff, rather fine-grained and with more clay than the sand along Little Ocmulgee River, and of little value for concrete, although suitable for brick and plaster mortar.

Oconee River.—Oconee River, which forms the eastern boundary of the county, has in its bed and in the numerous bars at the outside of the curves, immense quantities of excellent medium- to coarse-grained brown sand, well suited for concrete work. Cuts for the bridge crossing the river between Glenwood and Mount Vernon showed older deposits of cross-bedded, coarse sand interbedded with clayey and silty layers, lying within 1,500 feet of the river and forming the terrace just above the level of the river swamp.

Other deposits.—A small gravelly deposit was noted on the Glenwood-Lumber City road, 3½ miles south of Glenwood. The deposit did not exceed 2 feet in thickness and consisted of quartz pebbles up to one inch in diameter with over 60 per cent sand and extended for 1,000 feet along the road.

In the western part of the county the weathering of a quartz conglomerate of Alum Bluff age has given rise to small deposits of good gravel, which have been utilized in local road construction.

WILCOX COUNTY

No commercial sand is exploited in Wilcox County, although Ocmulgee River has abundant supplies. The surface of a large part of the county is covered with a layer of gray sand from a few inches to a foot or more in thickness, but good sand in quantity is scarce. Local supplies are generally obtained from ditches, where it has been heaped by rain, or from the vicinity of streams.

Small quantities occur on the banks of Allapaha River in the southern part of the county, and medium-grained sand is found in the beds of House, Bluff, and Folsom creeks. None of these deposits, however, are of any but local value.

Small areas of quartz gravel from a fraction of an acre to several acres in extent, and usually under 2 feet in thickness, occur in various parts of the county. Although such deposits are of little commercial value, they will be of value for local road construction.

WILKINSON COUNTY

No sand or gravel deposits are worked commercially in Wilkinson County.

Gordon.—Between Gordon and McIntyre a sandy belt is encountered, probably a northward extension of that so prominent in Crawford and Taylor counties. The sand is gray or yellowish, fine-grained, and ranges from a few inches to 10 feet thick in places. The Central of Georgia Railway runs through the belt.

Commissioners Creek.—The north fork of Commissioners Creek, one mile east of the Central of Georgia Railway crossing and 4 miles north of Gordon, has a wide valley, in which a medium- to coarse-grained yellow to brown sand, in quantities large enough for all local road-building purposes, occurs. Southwest of the creek, 1,000 feet back from the stream, the sand is coarse and pebbly and occupies deposits from a fractional part of an acre up to an acre in size.

On the same stream, where the Milledgeville-Gordon road crosses it, 2 miles north of Gordon, a bank deposit of gray, clean, pebbly, unstratfied sand occurs south of the creek. The deposit occupies a strip 200 to 300 feet wide and ranges from 5 to 10 feet thick, overlying a yellow clay. It appears to follow the stream for some distance, especially to the westward, although it also is found in the stream bed to the eastward. The Central of Georgia Railway runs about a half mile east of the deposit. Sample *T-59* represents the sand, and a mechanical analysis shows a fineness modulus of 2.59 and 92 per cent retained on the 48-mesh screen. The sand has practically no organic matter. It is composed mostly of quartz with a little feldspar that is altering to kaolin. A few small grains of ilmenite are visible.

Sand in irregular patches occurs further south of the stream and generally parallel to it. At McIntyre, Wriley, and Toomsboro, the creek has excellent sand, and it is used locally at these places.

Big Sandy Creek.—On the Gordon-Jeffersonville road, considerable medium- to coarse-grained sand occurs in the bed of Big Sandy Creek and along its banks for 200 feet back from the stream. Sand in quantities sufficient for concrete road purposes, and possibly for shipment, occurs all along this creek, however, rail transportation is lacking at any point along it in Wilkinson County. Three miles south of Irwinton on the Jeffersonville road there is a large deposit of excellent medium- to coarse-grained sand along this same creek.

WORTH COUNTY

Ocala, Chattahoochee, and Alum Bluff deposits, respectively, underlie the northwest corner of Worth County as one goes toward the southeast. The remainder of the county is covered with the irregularly colored sandy clays and feldspathic sands of the Altamaha formation. No sand is produced commercially in the county, and the local demand is supplied from concentrations of the surficial sand in ditches and along streams. The gray surficial sands produced by the leaching of the underlying clayey sands, or deposited by the wind, range from a few inches to several feet in depth.

TESTS OF COASTAL PLAIN SANDS

Number	Locality	Percentage coarser than each sieve													Effec. size	Uniformity coefficient	Fineness modulus	Specific gravity	Voids percentage	Weight per cu. ft.	Weight per cu. yd.	Color value of organic matter	Page number of text description	Number
		4	6	8	10	14	20	28	35	48	65	100	150	200										
10	Hardy's Crossing, bk.	----	0.1	0.4	1.2	3.9	12.2	28.5	49.8	68.7	82.3	91.8	95.7	98.7	.160	2.20	1.93	2.67	38.3	102.3	2762	trace	161	10
11	Dublin, bk.	----	----	0.1	0.9	4.5	19.2	51.5	88.7	98.6	99.6	99.6	99.8	99.9	.402	1.68	2.54	2.66	40.7	98.4	2657	1000	211	11
13	Dublin, Oconee R.	----	0.1	0.3	1.3	5.2	7.9	48.8	83.2	96.9	99.8	99.6	99.8	99.9	.356	1.80	2.51	2.66	39.2	101.0	2727	100	212	13
15	Lumber City, pit	3.2	6.9	10.8	16.8	24.7	36.0	49.7	65.2	77.8	92.4	98.7	99.2	99.7	.223	3.42	2.65	2.67	42.5	95.6	2581	trace	257	15
18	Lumber City, glass sand	----	----	----	0.1	0.9	7.1	20.1	41.0	65.4	85.8	96.2	98.4	99.6	.183	2.32	1.83	2.66	37.4	104.0	2798	trace	271	18
21	Lumber City, glass sand	----	----	----	0.1	1.6	8.9	24.6	47.7	70.7	90.2	98.5	99.6	99.9	.209	2.27	1.95	2.66	36.8	105.0	2853	60	272	21
24	Blackshear, bk.	----	----	----	0.1	0.3	1.8	11.1	42.0	76.1	93.7	98.6	99.5	99.5	.227	1.88	1.86	2.69	38.3	96.9	2616	trace	228	24
27	Waycross, bk.	----	----	----	0.1	0.2	0.6	6.5	28.4	62.5	89.0	98.1	99.5	99.9	.201	1.87	1.67	2.67	40.1	97.0	2619	trace	227	27
29	Waltertown, bk.	----	----	----	0.6	2.9	6.3	12.7	30.2	60.1	81.5	94.9	98.2	99.7	.170	2.22	1.71	2.66	38.0	103.1	2784	1500	228	29
31	Everett City, pit	----	----	0.1	0.3	0.5	0.9	7.4	29.6	69.4	91,2	98.1	99.2	99.6	.213	1.81	2.00	2.66	37.2	102.9	2778	500	218	31
32	Ludowici, bk.	----	----	----	0.1	0.4	1.9	8.5	32.8	65.8	88.9	98.6	99.7	99.9	.199	1.96	1.73	2.67	38.3	100.8	2722	600	215	32
33	Crescent, bk.	----	----	----	0.1	0.2	0.4	0.6	1.5	5.3	14.2	57.0	92.1	99.3	.107	1.59	0.63	2.69	42.5	96.6	2608	150	218	33
34	Savannah, cr.	----	----	----	0.7	2.8	7.9	18.8	41.3	66.5	86.8	97.7	99.3	99.9	.190	2.25	1.86	2.67	34.2	110.0	2970	200	173	34
35	Savannah, Savannah R.	----	----	0.2	0.7	1.9	6.3	24.1	64.3	93.0	99.6	99.95	100.0	100.0	.308	1.69	2.19	2.67	37.6	104.0	2798	100	173	35
43	Augusta, bk.	2.1	4.1	6.8	11.0	16.3	26.1	44.9	70.8	89.5	96.7	99.3	99.7	99.9	.289	2.29	2.49	2.66	39.4	100.6	2716	20	235	43
45	Augusta, pit	1.9	2.9	4.2	7.9	13.0	21.9	38.7	66.0	88.3	97.2	99.3	99.7	99.9	.278	2.09	2.45	2.66	36.0	106.0	2862	50	------	45
49	Stillmore, bk.	----	----	----	0.1	0.3	1.3	4.6	16.5	42.2	76.0	95.6	99.0	99.9	.164	1.86	1.43	2.66	41.0	96.5	2606	200	------	49
51	Kite, bk.	----	----	0.1	0.2	1.7	8.5	24.9	52.0	74.3	87.7	95.1	97.4	99.3	.189	2.60	1.96	2.66	37.5	103.8	2804	trace	209	51
52	Louisville, bk.	----	0.1	0.2	0.5	1.2	4.9	16.9	50.3	81.0	94.7	99.0	99.5	99.8	.237	1.98	1.98	2.66	39.0	100.5	2714	60	207	52
59	Gordon, bk.	0.3	0.6	0.8	2.0	5.6	16.2	41.4	74.5	92.5	97.8	99.5	99.8	99.9	.312	1.93	2.40	2.64	40.6	98.0	2646	10	274	59
60	Carrs Station, bk.	----	0.7	2.0	5.2	15.5	34.5	59.5	79.8	89.8	94.4	97.0	98.7	99.5	.292	2.67	2.62	2.66	36.2	105.0	2835	200	203	60
61	Gaillard, washed sand.	----	----	0.2	0.7	2.6	8.4	21.5	44.3	67.9	85.7	95.6	98.5	99.7	.181	2.48	1.88	2.67	38.0	103.4	2792	100	184	61
62	Gaillard, natural sand	----	0.5	1.5	4.4	8.3	15.7	26.8	46.4	66.0	83.6	93.1	96.6	99.0	.167	2.83	1.98	2.66	38.5	102.2	2487	40	185	62
63	Macon, bk.	----	----	0.1	0.3	0.6	2.0	9.9	40.9	69.9	87.8	94.7	97.0	98.6	.183	2.31	1.75	2.66	42.3	95.9	2589	trace	160	63
63a	Gaillard, abrasive	----	----	----	0.1	0.3	1.2	5.2	16.5	37.5	63.4	84.2	93.2	97.8	.119	2.41	1.27	2.66	42.1	96.3	2600	trace	183	63a

NOTE: R=river, cr=creek, bk=bank.

TESTS OF COASTAL PLAIN SANDS

Number	Locality	Percentage coarser than each sieve													Effec. size	Uniformity coefficient	Fineness modulus	Specific gravity	Voids percentage	Weight per cu. ft.	Weight per cu. yd.	Color value of organic matter	Page number of text description	Number
		4	6	8	10	14	20	28	35	48	65	100	150	200										
64	Gaillard, concrete	----	----	0.2	0.4	1.7	7.0	17.9	33.8	52.0	70.4	86.8	95.5	98.2	.131	2.89	1.59	2.66	36.1	106.2	2867	10	183	64
67	Roberta, pit	----	----	0.2	0.7	1.5	4.2	11.7	29.9	51.3	73.3	88.0	94.0	99.7	.134	2.68	1.53	2.68	40.0	100.0	2700	25	186	67
70	Zenith, pit	----	----	0.2	0.6	2.9	12.3	33.9	59.9	79.1	90.0	96.1	98.2	99.5	.208	2.64	2.12	2.66	47.3	87.5	2362	trace	182	70
75	Mauk, pit	----	----	0.1	0.4	1.2	4.3	14.3	36.0	56.1	76.3	90.2	95.1	98.4	.148	2.66	1.64	2.66	45.7	90.1	2433	25	252	75
76	Norwich	----	0.1	0.3	0.8	2.2	5.4	12.1	25.5	46.2	70.9	88.0	95.7	98.5	.136	2.44	1.49	2.66	37.4	104.0	2808	trace	251	76
77	Junction City, pit	----	----	----	0.5	2.7	6.4	13.2	31.8	59.9	82.8	95.9	98.7	99.9	.174	2.19	1.72	2.64	42.5	95.0	2751	12	243	77
78	Junction City, pit	----	----	0.2	0.7	3.1	10.8	27.4	47.9	63.0	76.4	88.3	93.5	97.9	.129	2.98	1.82	2.67	36.5	105.7	2854	200	246	78
79	Junction City, pit	----	----	0.2	0.5	2.3	9.3	25.5	51.4	70.7	83.7	92.3	95.9	98.8	.163	3.03	1.91	2.66	38.0	103.1	2784	trace	------	79
81	Junction City, pit	----	----	----	----	0.1	0.2	2.3	17.1	44.0	71.0	91.5	96.8	98.9	.151	2.08	1.38	2.67	39.9	100.3	2708	200	245	81
82	Howard, pit, unwashed	----	----	----	----	0.2	0.6	3.2	16.6	42.8	72.1	91.3	97.7	99.6	.151	2.04	1.37	2.66	41.0	98.0	2646	trace	247	82
83	Howard, washed sand	----	----	0.1	0.6	2.3	7.3	19.6	40.6	61.4	81.3	94.3	98.5	99.8	.167	1.79	1.78	2.66	38.7	102.0	2754	trace	248	83
84	Howard, tailings	----	----	----	----	0.1	0.8	4.2	12.9	25.1	38.7	59.1	72.3	91.3	.076	2.70	0.88	2.66	42.3	94.6	2554	25	248	84
87	Howard, pit	----	----	----	0.1	1.7	6.6	18.1	37.7	58.6	77.5	91.7	96.7	99.0	.154	2.69	1.70	2.65	39.1	101.0	2727	trace	249	87
88	Howard, white sand	----	----	----	----	0.3	1.4	8.9	35.9	64.0	86.1	95.7	98.1	99.6	.183	2.18	1.69	2.66	40.0	99.4	2681	trace	249	88
89	Dry Ridge, pit	----	----	0.2	2.5	8.4	16.0	39.4	64.3	78.7	88.9	95.5	97.7	99.5	.198	2.90	2.22	2.69	37.4	105.4	2847	100	252	89
92	Columbus, Bull Creek	6.1	8.3	10.6	15.5	23.0	31.5	54.6	76.0	90.5	97.6	99.7	99.9	100.0	.300	2.46	2.85	2.63	37.7	102.6	2771	50	223	92
93	Columbus, Upatoi Cr.	8.9	12.5	14.7	20.2	31.6	39.5	62.9	78.2	93.4	98.2	99.9	100.0	100.0	.322	2.57	3.11	2.66	37.4	104.2	2813	15	226	93
95	Fort Benning	11.4	15.4	20.3	29.3	38.1	54.7	69.2	82.6	91.8	97.5	99.4	99.7	99.9	.319	3.54	1.77	2.66	38.2	102.7	2773	25	------	95
207	Lampkins, Ocmulgee R.	0.2	0.2	1.3	7.8	25.4	60.5	88.2	98.4	99.7	99.9	100.0	100.0	100.0	.559	1.84	3.15	2.66	40.5	98.9	2670	50	258	207
210	Albany, pit	----	----	----	----	0.2	2.0	15.8	54.0	88.2	97.9	99.7	100.0	100.0	.287	1.73	2.04	2.69	42.7	96.0	2592	trace	192	210
211	Blakely, pit	----	----	----	----	0.2	2.9	20.7	54.8	99.1	99.5	100.0	100.0	100.0	.308	1.59	2.15	2.64	35.8	105.0	2635	700	194	211
213	Gradyville, bk.	1.2	2.4	3.7	7.0	10.6	16.5	25.9	39.9	53.1	65.0	80.0	88.3	95.9	.097	4.29	1.75	2.69	33.9	110.3	2978	50	201	213
214	Thomasville, Ocklocknee R.	0.3	0.7	1.2	2.8	5.8	12.4	25.7	49.6	75.2	91.9	98.2	99.3	99.8	.218	2.22	2.06	2.67	34.2	109.8	2965	125	260	214
216	Thomasville, Ocklocknee R.	----	----	----	0.3	0.7	2.2	8.2	26.5	54.8	80.2	96.3	99.1	99.8	.171	2.10	1.60	2.64	34.7	108.4	2916	40	260	216

TESTS OF COASTAL PLAIN SANDS

Number	Locality	Percentage coarser than each sieve													Effec. size	Uniformity coefficient	Fineness modulus	Specific gravity	Voids percentage	Weight per cu. ft.	Weight per cu. yd.	Color value of organic matter	Page number of text description	Number
		4	6	8	10	14	20	28	35	48	65	100	150	200										
217	Williams Station, pit	----	1.3	4.3	11.9	19.4	29.0	39.9	55.2	67.6	78.0	87.2	93.3	97.6	.128	4.59	2.18	2.67	34.8	108.7	2935	trace	261	217
219	Camilla, bk.	----	----	0.1	0.6	1.4	3.5	10.0	27.2	51.4	59.5	83.7	92.6	97.6	.117	3.01	1.47	2.66	39.3	99.0	2673	200	220	219
220	Newton, Flint R.	----	----	----	----	0.2	2.0	3.9	23.7	59.3	89.7	99.2	99.9	100.0	.206	1.75	1.63	2.66	40.2	99.5	2687	175	220	220
221	Newton, bk.	----	----	----	----	0.05	0.1	0.2	1.2	7.4	27.1	62.7	80.6	94.7	.084	2.21	0.70	2.63	39.7	99.1	2676	200	154	221
222	Albany, pit	----	----	----	----	0.05	0.2	0.5	4.4	40.6	83.5	98.9	99.6	99.9	.182	1.63	1.40	2.66	39.7	100.2	2705	100	213	222
231	Americus, pit	----	----	0.1	1.0	5.9	21.3	45.8	69.6	80.3	86.7	92.8	96.1	98.6	.175	3.69	2.26	2.66	39.7	100.1	2703	trace	241	231
232	Americus, pit	----	----	0.2	0.7	2.4	7.2	15.7	35.1	64.2	86.7	95.6	98.5	99.6	.185	2.14	1.78	2.69	41.9	97.8	2641	trace	242	232
234	Chatterton, pit	----	----	----	0.2	1.1	5.2	17.8	43.8	73.0	91.9	98.6	99.4	99.8	.217	2.05	1.91	2.67	39.4	101.0	2727	trace	179	234
235	Fitzgerald, pit	1.4	4.6	8.0	14.7	22.7	35.9	55.3	77.3	87.7	93.3	95.8	96.9	97.9	.259	3.02	2.71	2.67	36.8	105.6	2851	trace	156	235
236	Tifton, glass, pit	----	----	0.1	0.2	0.4	0.9	4.1	17.8	44.0	76.6	92.7	99.1	99.3	.157	2.00	1.41	2.67	35.8	107.1	2892	50	263	236
237	Nashville, pit	----	----	----	----	0.1	0.4	2.4	15.3	44.4	79.4	94.7	97.7	99.2	.174	1.79	1.42	2.67	39.1	101.5	2741	500	158	237
238	Adel, glass, pit	----	----	----	----	0.1	0.2	0.4	3.8	24.6	50.1	70.5	82.2	94.4	.084	2.89	0.96	2.64	35.8	105.6	2851	trace	181	238
239	Moultrie, pit	----	0.2	0.5	1.3	3.0	6.7	13.5	25.2	41.0	57.5	76.0	86.8	95.3	.093	3.32	1.34	2.67	35.1	108.1	2919	800	180	239
240	Quitman, pit	----	0.1	0.4	2.0	5.7	12.5	21.7	34.4	45.6	58.4	75.6	88.7	95.1	.098	3.65	1.49	2.66	43.3	94.0	2538	100	166	240
241	Quitman, Withlacoochee R.	----	1.3	1.7	2.6	4.7	9.6	19.3	35.8	53.0	71.5	81.3	94.1	99.0	.119	3.27	1.67	2.66	36.4	105.6	2851	100	216	241
242	Statenville, bk.	----	0.2	0.6	1.6	3.9	8.7	17.5	32.2	50.1	68.0	83.2	89.1	95.2	.099	3.68	1.54	2.66	41.6	97.1	2622	125	195	242
243	Alma, bk.	----	----	----	----	0.1	0.6	3.1	15.8	41.0	76.5	95.7	98.7	99.8	.165	1.82	1.40	2.67	42.2	96.3	2600	100	153	243
244	Helena, bk.	----	----	----	0.3	1.0	4.6	15.1	36.2	61.1	80.5	91.6	95.5	97.8	.156	2.55	1.69	2.67	38.3	102.8	2776	100	------	244
245	Cochran, cr.	----	0.4	1.2	3.5	7.8	18.5	32.8	54.6	74.8	88.6	96.3	98.1	99.3	.197	2.70	2.13	2.67	38.3	102.8	2776	100	165	245
246	Perry, pit	----	----	----	0.2	0.4	0.7	1.2	2.7	7.3	21.3	60.4	83.3	95.6	.088	2.04	0.69	2.66	41.7	96.9	2616	300	204	246
247	Tivola, pit	----	----	----	0.1	0.9	5.5	20.0	48.3	75.1	89.6	96.8	98.8	99.7	.208	2.25	1.93	2.66	37.7	103.6	2797	200	205	247
250	Montezuma, Flint R.	5.9	7.3	9.2	11.9	16.1	23.8	38.2	60.8	82.2	94.7	98.8	99.5	99.8	.241	2.80	2.50	2.67	39.7	100.5	2714	80	216	250
251	Eden, Ogeechee R.	----	----	----	0.4	1.0	3.1	11.1	33.5	65.9	91.3	99.0	99.7	99.9	.212	1.85	1.77	2.66	38.2	102.7	2773	25	197	251
252	Fort Benning, pit	1.6	2.8	5.0	10.1	18.7	41.0	59.2	75.5	88.4	95.4	93.6	98.6	99.5	.275	2.08	2.70	2.67	36.4	106.0	2862	50	------	252

TESTS OF COASTAL PLAIN SANDS

Number	Locality	Percentage coarser than each sieve													Effec. size	Uniformity coefficient	Fineness modulus	Specific gravity	Voids percentage	Weight per cu. ft.	Weight per cu. yd.	Color value of organic matter	Page number of text description	Number
		4	6	8	10	14	20	28	35	48	65	100	150	200										
252	St Simon Island, black sand	----	----	----	----	----	----	----	----	0.1	1.9	17.6	40.8	91.0	.075	1.40	0.18	----	----	----	----	----	357	252
262	Keysville	----	----	0.1	0.3	0.4	1.9	10.2	33.1	67.9	88.4	96.8	98.7	99.7	.197	2.42	1.75	2.62	n. d.	n. d.	n. d.	n. d.	169	262
263	Waynesboro, pit	0.1	0.4	1.2	2.6	5.0	9.3	16.7	29.0	54.4	73.7	90.4	95.9	98.9	.149	2.44	1.68	2.67	36.3	106.2	2869	200	169	263
264	Statesboro, pit	----	0.1	0.4	2.6	6.1	12.4	25.9	54.5	80.4	95.0	99.1	99.7	99.9	.238	2.09	2.12	2.64	36.7	104.4	2719	150	168	264
265	Canoe, bk.	----	----	0.1	0.2	0.5	1.8	9.5	31.9	64.9	86.4	96.5	98.5	99.6	.180	2.15	1.71	2.66	37.6	103.7	2800	175	171	265
266	Vidalia, bk.	----	----	----	----	0.3	1.7	6.2	16.3	37.7	65.6	84.7	94.9	98.1	.125	2.30	1.29	2.67	36.3	106.2	2867	200	264	266
267	Pendleton, bk	----	----	----	----	----	1.0	8.7	25.6	62.9	83.0	97.3	99.3	99.8	.178	2.08	1.69	2.67	38.2	103.1	2784	500	264	267
268	Gaillard, pit	----	0.1	0.6	1.7	4.9	12.2	26.1	47.6	71.3	86.5	94.6	97.7	99.3	.182	2.62	1.98	2.66	39.1	101.2	2752	100	----	268
269	Cussetta, bk.	----	0.1	0.3	1.0	4.0	12.1	26.6	51.6	75.7	85.7	93.5	96.3	98.4	.175	2.84	2.00	2.67	37.9	103.7	2800	600	175	269

TESTS OF COASTAL PLAIN GRAVELS

Number	Locality	Total per cent coarser than each sieve																Fineness modulus	Per cent of clay washed out	Page number of text description	Number
		1¼	¾	½	4	6	8	10	14	20	28	35	48	65	100	150	200				
19	Alamo, pit	16.0	53.1	69.1	86.2	87.6	88.7	89.8	90.6	91.7	93.1	94.6	95.9	97.0	97.9	98.5	99.3	6.91	9.3	268	19
36	Fleming, pit	----	----	5.2	59.2	67.3	73.0	78.2	81.0	83.9	88.1	90.1	95.1	97.2	98.7	99.3	99.7	5.00	14.7	215	36
41	Augusta, pit	8.0	21.2	38.4	40.4	59.0	67.9	77.9	84.5	89.3	93.5	97.1	98.8	99.2	99.4	99.6	99.8	5.52	15.1	234	41
42	Augusta, pit	----	11.3	27.5	55.0	60.8	63.9	67.9	70.9	74.8	79.9	86.6	91.8	94.2	96.2	97.2	98.0	4.97	14.6	234	42
46	Augusta, pit	8.0	19.0	30.0	42.0	46.4	48.6	51.2	52.7	54.2	58.4	65.2	79.0	89.8	97.2	99.0	99.6	4.35	13.7	236	46
48	Augusta, pit	----	----	6.6	22.4	28.0	31.6	34.4	36.4	39.2	46.0	58.3	71.4	86.1	95.6	98.4	99.6	3.10	6.1	-----	48
50	Swainsboro, bk.	52.3	70.8	76.9	83.8	84.5	85.0	86.5	88.8	91.4	93.9	95.7	96.6	97.3	98.0	98.5	99.2	7.46	10.4	198	50
54	Stapleton, pit	20.0	28.4	40.0	56.9	59.1	60.4	62.8	65.6	69.2	73.8	78.0	84.0	90.4	94.9	96.7	98.2	5.24	6.1	207	54
55	Warrenton	37.5	52.3	59.1	77.2	80.1	82.6	85.0	86.2	87.5	88.8	90.5	92.9	95.4	97.0	98.0	99.0	6.74	8.3	334	55
56	Norwood, pit	17.7	48.1	64.6	75.0	77.1	80.0	82.5	84.3	87.1	88.5	91.2	93.4	96.0	98.4	98.9	99.2	6.50	9.7	337	56
60	Macon, bk.	18.5	40.7	52.8	75.9	78.3	81.4	----	86.3	----	91.0	----	96.1	----	98.1	98.9	99.5	6.46	12.0	162	60
66	Macon, pit	15.6	42.9	55.5	73.4	77.5	81.8	86.0	88.0	90.0	91.8	93.8	95.8	97.5	98.9	99.4	99.8	6.44	14.3	164	66
71	Reynolds, bk.	28.2	53.8	79.5	94.9		no	t sift	ed											255	71
72	Reynolds, bk.	27.5	43.5	56.5	73.9	----	79.7	----	84.7	----	90.2	----	95.6	----	98.2	99.1	99.5	6.50	11.2	256	72
73	Beechwood, pit	----	----	25.5	45.4	----	54.5	----	69.2	----	87.2	----	95.5	----	99.0	99.3	99.7	4.76	12.0	254	73
74	Carsonville, bk.	49.1	62.3	67.5	78.9	----	83.9	----	89.4	----	92.5	----	96.1	----	98.3	98.7	99.0	7.18	8.4	254	74
90	Columbus, pit	6.6	19.8	52.2	75.0	78.1	80.4	82.3	84.2	86.7	90.5	95.3	98.3	99.4	99.8	99.9	100.0	6.07	4.8	223	90
91	Torch Hill, pit	12.9	30.8	43.1	58.5	----	68.2	----	76.7	----	83.1	----	91.5	----	98.7	98.9	99.3	5.63	7.3	224	91
95	Upatoi Creek, bk.	1.09	20.9	40.1	60.9	65.6	69.0	72.4	75.0	78.5	82.9	89.4	95.8	98.1	99.0	99.4	99.8	5.44	6.1	174	95
208	Lumber City, pit	3.18	20.9	44.3	47.5	63.0	74.7	84.4	89.7	93.8	96.0	96.8	97.3	97.9	98.5	98.9	99.4	5.72	10.2	258	208
212	Fort Gaines, pit	3.1	16.9	36.2	60.8	65.6	68.5	71.7	74.8	79.2	84.9	92.2	96.3	97.9	98.7	99.1	99.5	5.40	6.3	176	212
223	Georgetown, pit	20.3	28.8	38.1	80.5	83.3	84.9	86.7	88.3	90.1	92.3	94.6	96.7	98.5	99.5	99.8	99.9	6.29	5.9	230	223

TESTS OF COASTAL PLAIN GRAVELS

Number	Locality	Total per cent coarser than each sieve																Fineness modulus	Per cent of clay washed out	Page number of text description	Number
		1¼	¾	½	4	6	8	10	14	20	28	35	48	65	100	150	200				
224	Georgetown, cr.	15.1	39.0	49.7	66.1	69.5	71.9	74.8	76.8	80.5	85.1	90.3	93.5	95.9	98.4	99.3	99.8	5.96	n. d.	231	224
225	Fort Gaines, Magruder cr.	11.4	28.6	38.2	57.1	62.6	66.0	70.4	74.5	79.1	84.8	90.7	94.6	97.5	98.9	99.3	99.7	5.54	n. d.	176	225
226	Omaha, pit	13.5	29.8	45.2	69.2	----	75.6	----	79.2	----	82.6	----	87.2	----	92.4	------	------	5.75	7.1	240	226
227	Omaha, bk.	26.3	37.3	50.0	67.7	70.4	72.9	76.3	79.3	83.3	87.9	93.7	97.8	99.4	99.9	100.0	100.0	6.19	7.6	239	227
228	Omaha, bk.	8.4	22.9	38.1	66.4	70.9	74.1	77.2	79.9	82.6	85.5	88.2	91.3	93.8	96.3	97.8	99.1	5.63	7.2	238	228
229	Omaha, bk.	13.6	35.0	46.4	65.0	----	72.3	----	78.2	----	87.1	----	93.9	----	96.5	------	------	5.88	6.4	238	229
230	Omaha, Hannahatchee cr.	20.8	30.0	34.6	47.7	49.3	50.8	55.2	61.1	71.2	82.7	92.5	96.9	98.5	99.2	99.6	99.9	5.24	n. d.	240	230
249	Montezuma, bk.	----	5.8	10.9	34.1	----	48.9	----	61.3	----	73.7	----	88.1	----	96.2	------	------	4.19	14.6	------	249
273	Bell's Ferry, Oconee R.	----	3.2	19.1	41.9	47.2	52.1	57.9	63.0	68.2	74.0	81.9	88.6	95.2	99.3	99.7	99.9	4.41	n. d.	------	273

THE CRYSTALLINE AREA[1]

EXTENT AND SIZE

The Crystalline area in Georgia extends northwestward from the Fall Line to the South Carolina, North Carolina, Tennessee, and Alabama boundaries, and includes all but the following counties: Dade, Walker, Whitfield, Catoosa, Chattooga, Floyd and parts of Polk, Bartow, Gordon, and Murray counties. Its extent is limited on the southeast by the Coastal Plain sediments which have overlapped it.

PHYSIOGRAPHY

Piedmont Plateau.—The two outstanding features of the Crystalline area are the Piedmont Plateau and the Appalachian Mountains. The Piedmont Plateau which occupies about a third of the area of the state slopes gradually up from the rolling terrain near the Fall Line to its poorly defined junction with the Appalachian Mountains to the north. Between these limits it increases from about 500 to 1,200 feet in elevation. In places, more resistant strata have produced isolated knobs or ridges, such as Pine and Oak mountains, and Stone and Kennesaw mountains, which stand out above the rounded hills and the southwestward-trending ridges characteristic of of the Plateau.

Contrasted with the streams of the Coastal Plain those of the Piedmont Plateau are swifter, with narrower, deeper valleys and with falls and rapids fairly common.

Appalachian Mountains.—The southern end of the Appalachian Mountains, which extend along the eastern United States, southward from Pennsylvania, occupies a comparatively small triangular area in the extreme northern part of Georgia, noted for its beautiful scenery, and irregularly dotted with steep mountain groups between which narrow, fertile valleys and areas of broken country, lie.

---

1 Abstracted from the following sources:
Watson, T. L., Granites and gneisses of Georgia: Georgia Geol. Survey, Bull. 9-A, pp. 60-65, 1902.
McCallie, S. W., Mineral resources of Georgia: Georgia Geol. Survey, Bull, 23, pp. 15-16 32-33, 1910.

This division includes all of Rabun, Union, Fannin, Gilmer, and Pickens counties, and parts of Murray, Dawson, Lumpkin, White, and Habersham counties.

Although its average elevation is about 2,000 feet, some of the mountain peaks exceed 4,500 feet. They have been produced by the elevation of a former peneplain and its subsequent dissection. The irregular trend of the underlying rocks, together with their unequal hardness have contributed to the marked irregularity of these mountains as contrasted with those of the Appalachian Valley which adjoin them on the east.

The streams are generally swift and narrow with gravelly bottoms and high water falls not uncommon. Upon leaving the higher mountain area, they quickly widen out producing sandy and gravelly flood plains.

GEOLOGY

Piedmont Plateau.—The rocks underlying the Piedmont Plateau consist principally of schists and gneisses and subordinate amounts of granite, quartzite, and basic intrusions. Their age probably ranges from Archean to Triassic. Although usually highly metamorphosed by heat and pressure some of the rocks still retain evidence of unquestionable sedimentary origin, and others appear to be of igneous origin. In some localities their deformation has been so complete as to entirely prevent such a distinction. Their trend is usually N. 20°-30° E., and their dip generally is about 50° to the southeast.

Carolina gneiss.—The Carolina gneiss is believed to represent the oldest rock series in the Crystalline area. This formation occupies broad bands in which outcrops are scarce due to the deep weathering characteristic of our southern states. Excessive metamorphism has practically removed all indications of its origin. Micaceous and garnetiferous schist and biotite and muscovite gneisses form the greater part of the series.

Lenses and layers of medium-grained granite occur persistently through the gneiss. Much coarse sand and gravel occur in the streams flowing through the Carolina gneiss area, and the sand readily shows its origin in the numerous schist fragments occurring in it.

Roan gneiss.—The Roan gneiss consists of basic schists and gneisses, dark in color, and generally decidedly schistose in texture. Later intrusions of granite are common through the gneiss, in fact, they sometimes entirely replace it. The Roan gneiss weathers to a dark red clayey soil which makes the formation easily recognizable. It usually occupies long narrow bands conforming to the general northeast-southwest trend of the main structure. The gneiss is particularly extensive northward from the vicinity of Atlanta into the Appalachian Mountain area, and is also prominent in a narrow band just northwest of the Fall Line and paralleling it across the state. This series produces less sand and poorer sand than that derived from the other crystalline rocks.

INTRUDED ROCKS

The Crystalline area has been intruded during several periods by igneous rocks of widely differing composition.

Older igneous rocks.—Granites of early age, usually gneissic in structure, cut the Carolina and Roan gneisses in many places. They generally contain considerable biotite and are high in plagioclase feldspar. Peridotites, gabbros and similar rocks also occur intruding the older gneisses.

Younger granites.—Extensive areas in the Piedmont Plateau are underlain by granites, almost entirely lacking in schistosity, gneissic structure, and other evidences of metamorphic action. Their outcrop is marked by bare, table-like surfaces, or large rounded boulders. Mineralogically they are usually biotitic with lesser areas of muscovitic granite. Their weathering produces fairly large quantities of clean, quartz sand.

PINE MOUNTAIN QUARTZITE

Principally in Harris and Meriwether counties, quartzite, ranging from an impure schistose material to massive, granular, clean quartzite, outcrops in long, narrow, curving strips forming Oak and Pine mountains and several lesser extensions to the northeast. Sometimes the silica content is very high, suggesting its possible use in silica brick or even glass manufacture.

TRAP DIKES

Dikes of diabase or similar basic rock, probably of Triassic age, cut the rock of the Crystalline area at many points. Their linear extension is usually quite marked, and their occurrence particularly notable in a wide belt northward from Bibb County to the vicinity of Gainesville.

DETAILED DESCRIPTION OF INDIVIDUAL COUNTIES

BANKS COUNTY

No sand or gravel is produced in Banks County. Most of the streams, particularly Webb Creek, have fairly good sand.

Homer.—Webb Creek, where the Carnesville-Homer road crosses it, 2 miles east of Homer, has over 3,000 cubic yards of coarse-grained sand. Some mica, schist and feldspar is in the sand, particularly in coarse grains, but on the whole it is very good and suited for concrete aggregate. Sample *T-205 A*, obtained from this deposit, has a fineness modulus of 2.52 and 90 per cent is retained on the 48-mesh sieve.

Sand also occupies the bed of Hudson River for part of its course in the county, but no large uncovered deposits were seen.

Alto.—The Southern Railway operates a large ballast pit half a mile north of Alto, in a quartz schist, or friable quartzite having a little mica and feldspar scattered through it. The old pit is situated west of the railroad, covers 6 or 7 acres, and has faces from 35 to 40 feet high. The desirable rock has been worked out on this side, and another pit has been opened 1,200 feet east of the old pit, where the quartzite is first broken with small dynamite charges and then loaded into cars with a steam shovel. From 5 to 10 cars are shipped daily.

In both quarries the bedding is plainly visible, but in the newer quarry it is much thinner than in the old one. Two sets of joints traverse the rock. The beds dip uniformly to the east at an angle of 32° in the old pit and 29° in the recent opening. The strike ranges from N. 20° E. to N. 13° W. In the old quarry some crumpling is apparent, and the rock as a whole is much denser than that east of the railroad. It pinches out at both ends to a sandy clay and gives place on either side to a less siliceous schist. The rock in the new quarry is much softer and is replaced in many places by sand or clay. The overburden ranges from 3 to 12 feet in thickness and consists mostly of clay.

BARROW COUNTY

No sand or gravel is produced commercially in Barrow County.

Winder.—Marburg Creek, 3 miles south of Winder, on the Monroe road, is about 8 feet wide and has small bars of coarse-grained, muddy sand, with at least 10 per cent of the grains composed of schist, feldspar, and limonite. The sand should be suitable for most local purposes.

Five miles south of Winder, Shallow Creek, where crossed by the Monroe road, is 40 feet wide, and although shoaly, it has sufficient coarse-grained sand to supply demands for local construction purposes.

BUTTS COUNTY

No sand is produced for shipment in any part of Butts County. Ocmulgee River and smaller streams throughout the county have sufficient sand for local purposes if the transportation is adequate.

Sandy Creek.—At Indian Springs, Sandy Creek probably has more sand than any creek in the county. In laying the foundation for the bridge at this place 22 feet of coarse sand was encountered. The sand extends along the creek in its course through the county and is especially abundant just above the dam at the springs. The sand is coarse-grained and has a few particles of schist, feldspar, and limonite besides the quartz.

Rocky Creek.—Rocky Creek, in the southern part of the county, has sand in small bars which yield from 10 to 15 cubic yards each. The sand is coarse with some sub-angular and angular gravel. Blue clay forms the banks and underlies the sand, which is usually 3 to 4 feet thick. Sample *T-109* was taken from this creek at the Forsyth-Indian Springs road and is fairly typical of Butts County creek sand. The fineness modulus is 2.62 and 85 per cent is coarser than 48 mesh. The organic color value is 100. The sand is yellowish-brown due to clay coating the particles. Feldspar composes about 10 per cent of the sand and makes up that part of it retained on the 4- and 6- mesh sieves.

Yellowwater Creek.—Yellowwater Creek has good sand from Hodge's Mill to Ocmulgee River, although in smaller amounts than in Rocky Creek. A thick deposit is located at McCandless Bridge, 1¼ miles north of Jackson. Deson Branch of Yellowwater Creek also has good sand for local use.

Tussaha Creek.—Tussaha Creek, in the northwest part of the county, is backed up for 4 miles west of the river, but above this point there are several good sand bars, as well as sand in the backed creek which is not visible. Wolf Creek, a branch of Tussaha Creek, also has sand bars, in one place 18 feet having been encountered in excavating for a bridge foundation.

Indian and Cabin creeks in the southwest part of the county have sand. Sand is particularly prominent at Henley's Mill. Sand for use in construction work at Jackson is generally obtained from Town Creek, southeast of the city.

Ocmulgee River.—Ocmulgee River has large amounts of good sand. All the sand used in the construction of the great dam east of Jackson was obtained from this river. Shoals occur every few miles along the stream, but in the quiet reaches between, the sand accumulates and affords an abundant supply for any construction work that may be undertaken near the river. Lack of transportation prevents its commercial development at present.

CAMPBELL COUNTY

The streams of Campbell County usually have small amounts of sand along their courses. A branch of Line Creek, half a mile southwest of Fairburn on the Riverside road, has deposited many carloads of excellent sand in the fields along its course just north of the road.

Small amounts of good sand are also found along Deep, Camp, Whitewater, Utoy, Bear, and Pea creeks. Large quantities of excellent sand occur in Chattahoochee River which forms the western boundary of the county. Although no railroad runs near the river, the sand can be recovered by centrifugal pumps and used for local construction work.

CARROLL COUNTY

Creek sand and gravel have been shipped in small quantities from some of the streams in the northern part of Carroll County. The sand in the streams of the county is generally a clean, coarse-grained material, well suited for concrete aggregate.

Carrollton.—Sand for local use in Carrollton is hauled from Curtis Creek, 1½ miles northeast of the town. It occurs along and in the creek in bars containing from 10 to 100 cubic yards and easily supplies the local demand. Sample *T-126*, from this creek, has a fineness modulus of 2.09 and 70 per cent is coarser than 48 mesh. Only a trace of organic matter occurs in the sand. The sand is yellowish-brown. Schist and limonite particles mostly in coarse grains, compose 15 per cent of the sand.

The beds of both Little Tallapoosa and Chattahoochee rivers, are rather muddy, but some poor sand is found in a few places along their courses.

Turkey Creek, on the Burwell-Kansas road, has a large amount of very high-grade sand and gravel. Jumping-in Creek, a branch of Turkey Creek, has deposits from 300 to 500 feet wide, along its course. This sand is not very thick, but it is a clean, white, medium-grained product desirable for concrete work.

In the vicinity of Lowell, in the southern part of the county, Whooping Creek has small quantities of good concrete sand. A small branch of this creek near Bay Springs, has a red, somewhat clayey, sand.

Bear Creek.—In the northern part of the county near Mandeville, Bear Creek and Buck Creek have fair quantities of excellent coarse sand and gravel mixed. Where the Mandeville-Mount Zion road crosses Bear Creek, Mr. J. T. Thompson, of Carrolton, hauls sand from the creek bed to the top of the hill, 2,000 feet east, where it is transferred to trucks and then loaded on cars on the Central of Georgia Railway. Sample *T-129* represents the sand from this bed. It has a fineness modulus of 3.28 and 96 per cent is retained on the 48-mesh screen. The organic color value is 150. The sand is buff-colored and 2 per cent is coarser than a half inch. It is composed mostly of iron-stained quartz and about 4 per cent of feldspar in the coarse grains.

Similar sand occupies the bed of Poplar Creek on George Ernest's land, a half mile east of Bowden Junction. Excellent sand is also found on J. W. Raburn's land from a half to three-quarters of a mile from the Junction.

Burwell.—One mile east of Burwell, on the Carrolton road, Boyle Creek is 8 feet wide and has fair quantities of good medium- to coarse-grained sand in its bed.

Snake Creek.—Snake Creek probably has the largest and best

A. CONCRETE SAND DEPOSIT ON BANK OF YELLOW RIVER, 1 MILE EAST OF ALMON ON COVINGTON ROAD, NEWTON COUNTY

B. SAND BAR IN APPALACHEE RIVER ABOVE STEEL BRIDGE, ATHENS-MADISON ROAD, OCONEE AND MORGAN COUNTIES sand deposit in Carroll County in a large bar just below Jones' Mill, east of Banning, in the southeast part of the county. This deposit is about 1½ miles from the Central of Georgia Railway. Excellent sand occurs in bars and in the bed of the stream for most of its course.

CHEROKEE COUNTY

No sand or gravel, except for local purposes, has been produced in Cherokee County.

Canton.—Town Creek, on the Marietta road, south of Canton, has bars of good concrete sand with from 300 to 500 cubic yards each. The coarser sand and gravel occupy the bed of the streams or bars close to the channel, and farther back, a finer-grained sand used in the local marble-finishing works, is found. Sample *T-181* is typical of the coarse concrete sand and has a fineness modulus of 3.40 and 91 per cent of it is retained on a 48-mesh sieve. The organic color value is 200. The sand is brown and has 8 per cent coarser than a half inch. About 15 per cent of the sand is feldspar; limonite, in rounded balls, and schist are also common.

The finer-grained sand, used in the rubbing beds and under the gang saws in the marble works, is represented by *T-182,* obtained along Town Creek. It has a fineness modulus of 1.49 and 50 per cent is retained on the 48-mesh sieve. Further up this same creek even larger deposits of sand and gravel similar to that at Canton are found.

A fine-grained, brown molding sand occurs on the banks of Town Creek from 3 to 6 feet thick. It is prominently exposed on the outside of the curves near the Marietta road, and although it contains some mica flakes, it should be suitable for foundry purposes (*T-183.*)

Sand is also obtained from the banks and bed of Etowah River just above the marble works and is used principally in cutting or polishing the marble and also for construction purposes. Mr. John Coggins handles sand for this purpose.

Sharp Mountain Creek has fine- to medium-grained sand in the stream bed and small scattered deposits of fine sand on the banks. The sand is dark brown and contains much schist, slate, and biotite, consequently, although it may be coarse-grained, it cannot be recommended for concrete of high specifications.

Gravel.—A belt of gravel passing through Canton, generally from east to west, is from 2 to 10 feet thick and has an excellent clay binder, making it desirable for road construction. Due to its occurrence in the built-up section of the town, it is difficult to use much of it. No other gravel has been found elsewhere in the county, although it would seem likely that deposits might be found if detailed search were made on the slopes and near the tops of the hills, or upper terrace, overlooking Etowah River and its larger tributaries near their junction with the river.

CLARKE COUNTY

No commercial sand or gravel has been produced in Clarke County. Deposits of excellent sand, however, are usually associated with the streams.

Middle Oconee River.—On the Watkinsville-Athens road, at Princeton bridge, a large deposit of excellent, coarse-grained quartz sand well suited for concrete purposes occurs in the stream bed. Probably several hundred cars of this sand could be obtained from the river just above the bridge and the size and swiftness of the stream would insure a constant replenishment of the sand. A finer-grained sand has also been deposited along the course of the river and further back from the channel. Silt layers, deposited during floods, usually occur with this finer sand. The Seaboard Air Line Railway crossing, 4 miles west of Athens, is the nearest rail point on the river, and it is likely that similar sand occurs in the river at that place. Sand obtained from the river at the Mitchell bridge was tested at the Georgia School of Technology and showed 137 and 114 per cent of normal at 7 and 28 days, respectively.

At the confluence of Barber and Magnus creeks on the Watkinsville road, a few miles beyond Oconee River, fairly large amounts of coarse-grained sand occur in the stream bed which is about 30 feet wide.

Athens.—Sand used locally in Athens is obtained principally from Trial Creek, just north of the city. This sand occurs in the creek bed in fairly large amounts and is of an excellent quality. Sample *T-115* is representative of this sand, and it was found to have a fineness modulus of 2.66 and 85 per cent of the sand coarser than 48 mesh. The organic color value is 50. The sand is a pale reddish-brown and about 1 per cent each of feldspar and mica occur in the sand.

Lester Creek.—Lester creek, on the Talassee road 4 miles from Athens, has fair quantities of very good sand, similar to that in Trial Creek and suitable for local purposes, although not sufficient for continued pumping.

Magnus Creek.—Magnus Creek, at the mill three-quarters of a mile south of the Athens-Winder road and 6 miles from Athens, has probably 200 carloads of sand just below the dam. This sand is medium to coarse-grained, and composed principally of quartz and feldspar and some mica flakes and schist fragments. The sand also occupies the stream banks 50 feet from the stream, which is about 25 feet wide at this point.

CLAYTON COUNTY

Sand was formerly produced at Rex along the Southern Railway in Clayton County, and considerable amounts suitable for local uses occur in the stream beds.

Rex.—On the Estes property at Rex, sand was formerly pumped by the Smiley Sand Company from a branch of Cotton Creek where it had collected in a mill-pond. In busy times about 4 carloads a week were shipped. The deposit was limited and was soon exhausted, as is the usual case in such small stream deposits. Considerable mud is said to occur with the sand. Since cessation of operations here it is likely that the mill-ponds along this creek have again become filled with sand and might warrant pumping. It is to be remembered, however, that the exhaustion of this sand will depend on the rate of pumping.

Jonesboro.—Some sand occurs in Mud Creek (Flint River), 1½ miles west of Jonesboro. It is medium-grained and of fairly good quality, and several thousand yards occupy the bed and banks of the stream. Four miles southwest of Jonesboro on the Fayetteville road, the same stream has a 700-foot bottom, and excellent coarse-grained sand from 2 to 8 feet thick occur in the bottom in fairly large quantities suitable for local use.

COBB COUNTY

Sand was formerly pumped from Nickajack Creek, near Nickajack station, and from Chattahoochee River, above Bolton. Considerable good sand occurs in Sweetwater, Proctor, and other creeks in Cobb County.

Acworth.—One mile south of Acworth on the Dixie Highway, Proctor Creek has large quantities of excellent coarse and fine sand and gravel. (Plate XVI-B.) The material is of white quartz, the pebbles ranging up to 4 inches in diameter, and the deposits are from

2 to 5 feet thick. The bars extend along the creek for several miles, alternating from one side of the stream to the other, and are capable of yielding from 200 to 1,500 yards of concrete aggregate each. Sample *T-180,* obtained from the creek just above the Dixie Highway and one mile south of Acworth, has a fineness modulus of 4.96 and 54 per cent is coarser than the 48-mesh sieve.

A smaller creek, 5 miles north of Marietta on the Dixie Highway, has excellent concrete sand. It forms a large deposit of several acres close to the road and apparently has several thousand cubic yards of sand. About a half mile further south on the same road, another branch has smaller quantities of good concrete sand in the stream bed and along the banks.

Marietta.—The streams and branches close to Marietta have good quantities of sand suitable for concrete and other building purposes. Gravel is said to occur at and near the top of the ridge of hills extending around the south side of the city. The gravel is exposed in a cut on the Louisville & Nashville Railroad just south of the town. The city has a small pit at the top of the ridge east of the Dixie Highway and near the railroad.

Nickajack Creek.—The Smiley Sand Company, of Atlanta, formerly pumped a coarse-grained sand from Nickajack Creek half a mile from Nickajack station. Four or five cars could be produced here daily, but some difficulty was encountered with the rocks and trash in the stream, and it is doubtful whether a steady supply exceeding 1 or 2 cars daily could be maintained year in and out.

Chattahoochee River.—Chattahoochee River has large amounts of excellent medium- to coarse-grained sand in its bed through most of Cobb County. The sand was formerly pumped commercially above the water works at Bolton by the Smiley Sand Company. During the freshet of December, 1919, the river deposited between 3 and 4 acres of fine- to medium-grained sand from 3 to 6 feet deep on the Cobb County side just above the River (Marietta) Road bridge. The Georgia Railway and Power Company has bought this deposit and has put in a spur and uses the sand for sanding rails and for construction purposes. That part of the deposit nearest the road is very fine-grained, but the eastern end has excellent medium- to coarse-grained sand with a few pebbles and is well suited for concrete aggregate.

COLUMBIA COUNTY

No sand or gravel is produced in Columbia County. On the

Thomson-Appling road, 7 miles from Appling, at White Oak (colored) Church, a strip of yellow, fine-grained sand, one mile wide, occurs. The deposit is at least 6 feet thick and is apparently an extension of the Fall Line sand-hill belt. The upper 3 feet of this sand is very fine-grained and of little value, but it becomes coarser below. Sample *T-110 A* showed a fineness modulus of 1.96 and 69 per cent coarser than 48 mesh. The organic color value is 200.

Appling.—Good, coarse-grained sand in fairly large quantities and suitble for local demands, occupies the bed of Big Kiokee Creek, just east of Appling on the Augusta road.

Greenbriar Creek, 3 miles west of Appling, is from 6 to 8 feet wide and has a very coarse sand, with fragments of schist and feldspar common. This sand is typical of the small streams in Appling County and is well suited for most concrete work. Sample *T-111,* taken from this creek on the Appling-Lincolnton road, has a fineness modulus of 3.21 and practically all of it was coarser than the 48-mesh screen. The sand is dark gray and contains about 7 per cent feldspar in coarse grains and numerous flakes of mica up to one-eighth inch.

Kegg Creek, a few miles further north, and about the same size as Greenbriar Creek, has sand similar to that in the latter creek.

Little River, which forms the northern boundary of the county, is usually very swift, but it was reported to have mostly a rocky bottom with little sand. Savannah River, which forms the northeast boundary of the county, should have large bars of good sand. It was reported, however, that there were only small quantities of sand either along or in the river.

Harlem.—Three miles west of Harlem, a red limonite gravel occurs along the Augusta road for 1,000 feet. In a cut on the Georgia Railroad paralleling the public road, it attains a maximum thickness of 4 feet. This material is somewhat irregular in its extent and may have a considerable thickness of clay above it. It makes an excellent road material, however.

A mile east of Harlem, in a railroad cut, two layers of quartz and limonite gravel may be seen, with pebbles up to 2 inches in diameter. The layers are about a foot thick and a foot apart. One to two feet of quartz gravel shows up in a railroad cut, and also along the Augusta road, 3 miles east of Harlem. A small pit has been opened on the Augusta road, 3 miles east of Harlem, and a sandy clay gravel has been used for road material.

COWETA COUNTY

The streams of Coweta County afford adequate supplies of sand for all local work, although none but Chattahoochee River is large enough to warrant commercial recovery.

Newnan.—Walton Creek, on the Roswell road northwest of Newnan, has small bars of medium- to coarse-grained sand. Similar sand is found in this stream on the Carrolton road near the Central of Georgia Railway crossing. The creek here is 20 feet wide with a rather rocky bed and the sand, although composed of hard quartz grains, usually has a large amount of cinders. On the Newnan-Atlanta road, 2½ miles from Newnan, there is a small amount of coarse, brown sand suitable for concrete and used in Newnan.

Three miles north of Grantville, on the Newnan road, a branch 10 feet wide has small bars of medium-grained sand which should yield 10 to 50 cubic yards each. Similar sand in larger quantities occurs along Sandy Creek in the western part of the county.

Line Creek, forming the eastern boundary of Coweta County, has fairly good, coarse-grained sand as does White Oak Creek, which is 20 feet wide on the Fayetteville-Newnan road. A branch of White Oak Creek only 6 feet wide on this road, 6 miles east of Newnan, has smaller amounts of good sand. Sample *T-122 A,* obtained from the last-named creek, is very typical of the character of the creek sands in this county. A mechanical analysis showed a fineness modulus of 2.62 and 98 per cent coarser than the 48-mesh sieve.

DAWSON COUNTY

No sand or gravel has been produced in Dawson County.

Excellent coarse-grained, yellow, quartz sand covers about 10 acres of the property of E. C. Burdine, a half mile east of Yellow Creek postoffice, and along Amicalola Creek. The deposit is from 2 to 4 feet thick and is underlain by blue clay. Similar but smaller deposits occur along the same creek on the Hill and Merian Voyles' properties.

Yellow Creek, in the southwest part of the county, has fine-grained, white sand along its banks and in the stream bed at numerous places.

Dawsonville.—Near Dawsonville, Shoal, Pigeon, and Flat creeks, and their branches have only small quantities of coarse sand, sufficient, however, for any local demands. Etowah River, which flows through the southern part of the county, has the largest deposits of sand in the county, usually in bars along its course. Coarse gravel occurs at Dougherty, but with very little sand.

Just south of Dixon, on the Gainesville road, a branch of Thompson Creek, 10 feet wide, has a coarse-grained sand 2 feet in thickness. A red clay lies beneath the sand.

Chestatee River.—Hundreds of carloads of coarse-grained sand have been deposited in Chestatee River above Glover's Mill. (See sample *T-197*, Hall County.) A large bar deposit occupies the bed of the stream just below the mill.

DEKALB COUNTY

Considerable quantities of sand are found in Peachtree and North creeks, and in and along Yellow River, but no commercial shipments have been made.

Decatur.—The sand used in Decatur is generally hauled from points along Peachtree Creek, 2 to 4 miles distant. Large amounts of good, medium- to coarse-grained sand occur on the W. J. Houston property, on Peachtree Creek below the Houston Mill road. From this place to the Seaboard Air Line Railway bridge from 10 to 50 carloads of excellent sand occur at many points in the stream.

Conley.—In the bed of North Creek, just north of Conley in Clayton County, and east of the Southern Railway trestle, a large deposit of coarse-grained, concrete sand occurs, containing about 4,000 yards. The sand is of excellent quality, and about 1915 an average of one carload a day was shipped from this point. The stream, however, does not appear to be large enough to replenish sand taken from it at that rate, and none has been shipped from there recently. Sample *T-5,* obtained from the creek bed, has a fineness modulus of 2.32 and 89 per cent is retained on the 48-mesh screen.

DOUGLAS COUNTY

No sand or gravel is mined in Douglas County, although most of the streams have fairly good sand in sufficient quantities for local purposes.

Sweetwater Creek and its branches in the eastern part of the county have fine-grained sand in the deeper parts, but where the stream is more shoaly good concrete sand occurs. Beaver Creek, near Lithia Springs, has very good, coarse-grained, quartz sand that is used locally. Camp Creek and Cane Creek in the southern part of the county have good coarse sand in small quantities along most of their courses.

Aneewakee Creek.—On the Douglasville-Chapel Hill road, Aneewakee Creek is 25 feet wide and has excellent, coarse-grained concrete sand both in the stream bed and along the banks. The latter is from 4 to 6 feet thick above the bridge, and the deposit near here contains about 1,000 cubic yards. Sample *T-130* was obtained from this creek and has a fineness modulus of 2.91 and 93 per cent of the sand is coarser than 48 mesh.

Bear Creek, in the western part of the county, has excellent sand, particularly on the Roach place and near Adamson's Mill. Dog River, in the southwest part of the county, has plenty of coarse sand in its bed. Deposits of sand have also been made in the flats along the stream. One of the largest deposits occurs near New Hope Church.

ELBERT COUNTY

The large amount of granite in Elbert County accounts for the high quartz content of the stream sands. Although none is produced commercially, the deposits are of a very high grade of sand, particularly those along Broad River.

Broad River.—Just below the steel bridge on the Elberton-Berkley road, is a large bar of clean, coarse-grained, quartz sand having a little feldspar and some limonite fragments. The river is shoaly at this point, but its speed insures the constant replenishment of the bar, which probably has over 10,000 cubic yards of sand. Similar deposits occur along the stream throughout most of its course in the county. (Plate XVII-A.)

Between the steel bridge and Elberton, Little Dove and Big Dove creeks, 10 and 20 feet wide, respectively, have good quantities of clean, coarse-grained, quartz sand.

Elberton.—Sand used in Elberton is obtained principally from Falling Creek, southwest of the town on the Jones' Ferry road. Most of the sand comes from the Dillard Brown property, although other deposits occur up and down the stream. The sand is yellow and medium-grained, but is suitable for concrete work. Sample *T-203 A*, represents the sand, and it shows a fineness modulus of 2.38 and 85 per cent coarser than the 48-mesh sieve. The color value of the organic content is 150.

Beaverdam Creek, on the Elberton-Hartwell road, is 30 feet wide, and has bars and deposits of medium- to coarse-grained sand from 2 to 5 feet thick. The stream bed is made up of finer-grained sand a foot or two thick with a large percentage of mica flakes and organic matter.

Morea Creek, in the northern part of the county, is 15 to 20 feet wide and a medium-grained quartz sand, suitable for concrete, occupies its course. The sand is yellowish and has some feldspar and limonite grains.

FANNIN COUNTY

No sand or gravel has ever been produced commercially in the county. The deposits of good sand in the county are generally very small, scattered, and in remote places.

Toccoa River.—The bed of Toccoa River is usually rocky, although some good deposits of sand and gravel are found in it. A very fine-grained sand has been deposited along its banks, suitable only for brick work. Sample *T-186*, obtained at the west side of the bridge on the Blue Ridge-Morganton road, has a fineness modulus of 1.30 and 36 per cent coarser than 48 mesh.

Bars of fairly good sand and gravel occur in Fightingtown Creek and in Hemptown Creek between Hemp and Blue Ridge.

FAYETTE COUNTY

The surface of Fayette County is rolling and underlain mostly with mica schist which is intruded by a porphoritic granite in the central part of the county.

Lowry.—Bank sand was formerly shipped from the west side of Flint River by Venable Brothers, of Atlanta, near the water tank on the Southern Railway, one mile north of Lowry Station. The sand is practically all removed from this deposit, although several hundred carloads of a yellowish, fine-grained sand might still be obtained. A finer, more clayey, reddish material is associated with the sharp sand, generally overlying it, and it appears to be suitable for some types of foundry work.

Further up Flint River, about 2 miles above the part described above, some fairly good deposits of medium-grained sand are said to occur on the left bank of the stream.

Whitewater Creek.—There is considerable good sand in Whitewater Creek above Bennett's dam, about 3 miles from Fayetteville. Small deposits occur along this creek suitable for local purposes.

Flat Creek, in the western part of the county, is 8 feet wide on the Fayetteville-Newnan road, and has small quantities of sand (from

10 to 50 cubic yards) in bars along its course. The sand is somewhat muddy with a considerable percentage of schist particles. Similar sand, but in larger quantities, is found in Line Creek, which separates Fayette County from Coweta County.

FORSYTH COUNTY

No sand or gravel has ever been produced in Forsyth County, although the streams generally have good amounts of fair sand, which is available and well suited for any local construction work that may be undertaken.

Cumming.—Big Creek and a branch of Vickery Creek, one mile west of Cumming on the Canton road, is 6 to 8 feet wide and affords the local supply. The sand is medium- to coarse-grained and has a large percentage of feldspar, limonite and mica. Concrete strength ratio tests of this sand made at the Georgia School of Technology, showed 101 and 93 per cent of normal at 7 and 28 days, respectively. Further down the creek the deposits become larger and the percentage of softer particles less.

Sitting Down Creek is very sandy throughout its course in the county, until within 3 miles of the Cherokee County line, where it becomes sluggish and deposits only silty sand and mud.

Chattahoochee River, which forms the eastern boundary of the county, has many bars and much coarse- and fine-grained sand in its bed for most of its course along the county.

FRANKLIN COUNTY

The streams of Franklin County should afford sufficient sand for most local purposes, although none is shipped.

The North Fork of Broad River, where the Bowersville-Carnesville road crosses it, is 50 or 60 feet wide, very shoaly and has some muddy, fine-grained sand along the stream and very dirty, medium-grained sand in small quantities in the stream bed. Sand having a large percentage of mica and limonite generally extends along the bank of the river.

Stephens Creek, south and southeast of Carnesville, is 8 feet wide and has small deposits of fairly coarse sand suitable for concrete purposes which are used locally.

West of Carnesville, the Middle Fork of Broad River is more rapid than the North Fork, but the sand is poor and has a great deal of clay and mud wherever the stream bed is not full of rocks.

Hudson River, forming the southern boundary of the county, has a coarse-grained sand of very good quality in large amounts, although it is inaccessible for most purposes at present.

FULTON COUNTY

Like most other North Georgia counties, the streams of Fulton County have large amounts of good, concrete sand.

Atlanta.—Sand for local uses in Atlanta is obtained from Peachtree, Utoy, Proctor, Clear, and many other smaller creeks and branches, either by pumping or by hand. Considerable sand is also gotten from accumulations in small branches and gullies in the less built-up portions of the city.

Acme Sand and Supply Company.—The Acme Sand and Supply Company owns land along Peachtree Creek near the intersection of the creek and Peachtree Road. The plant of the company is installed just east of the road about 200 yards south of the bridge. (Plate VI-B.) The sand is pumped from the stream with a 6-inch Trenary pump, made by the Mutual Foundry and Machinery Company, of Atlanta, and raised to 26 feet, where it is discharged on a rotating, cylindrical trommel having $\frac{3}{16}$-inch meshes which take out the twigs, cinders, and pebbles. The sand then passes down a wooden sluice to a wooden settling tank in which it collects. and from which the clay passes off in the water until the weight of the sand is sufficient to force down a circular iron valve which is held tightly against an opening in the bottom of the tank by a shaft to which a counterbalance is attached acting through a horizontal arm. The sand is then allowed to collect in a chute or boot from which, by raising a door, a one-yard tram-car can be loaded. The loaded car is pulled up an inclined track, 100 feet long, by a cable system operated by a gasolene engine, and dumped into bins facing on Peachtree Road, from which 3-ton auto trucks are loaded. (Plate VIII-A.) The sand is delivered to all parts of Atlanta, the price depending on the distance. Sample *T-1*, representing the washed sand, has a fineness modulus of 2.45 and 89 per cent is coarser than 48 mesh. The color value of the organic matter is 200.

Peachtree Creek, at the Acme Sand and Supply Company plant, is about 30 feet wide and normally from 1 to 2 feet deep. Sand can usually be pumped out to a depth of from 6 to 14 feet. The pumped sand passes through a maximum of 300 feet of 6-inch pipe, supported on barrel floats before reaching the pump-house. Little difficulty has been experienced in maintaining a fair supply of sand, although long spells of dry weather with no opportunities for the replenishment of the sand, may give trouble.

Peachtree Creek at other points along its course has large quantities of good sand. This is particularly true near its intersection with Piedmont Road, on the N. H. Cheshire property, and at its intersection with the Howell Mill Road.

Fulton County.—The Department of Public Works of Fulton County operates a 6-inch Morris centrifugal pump on the creeks in Fulton County to obtain sand for construction purposes. The pump has been at work on Utoy Creek, at Cascade Road during 1919, but in the spring of 1920 it was moved to South River on the Jonesboro Road. A 14-horsepower boiler and a 20-horsepower steam engine are used to operate the pump. From 1 to 5 cars of sand daily have been pumped from the creek, but such a production cannot be kept up constantly unless the season is rainy, and the streams are kept full of sand. The pump has also been operated on Utoy Creek on the Campbellton and Newnan roads, and on Proctor Creek at the Mason-Turner Road.

Proctor Creek.—Sand for local building purposes is obtained from Proctor Creek above Bellwood Avenue, and is also used by the Georgia Railway and Power Company to sand the street car rails in Atlanta. The sand is shoveled from the stream by hand into wagons from which cars are loaded. Sand is also obtained from this creek near the intersection with the River Road, a mile east of Riverside. Sand has also been gotton from Terrill Creek along the line of the Georgia Railway and Power Company.

Clear Creek.—Along Clear Creek, on the J. G. Johnson property, 200 yards west of Piedmont Avenue, close to its intersection with the Southern Railway, excellent, medium- and coarse-grained sand has collected. The deposit in this vicinity has several hundred cubic yards of sand and the material is hauled to nearby points for construction purposes.

Chattahoochee River.—The Smiley Sand Company of Atlanta formerly operated a pump on Chattahoochee River just above the water-works at Bolton. The sand obtained was of excellent quality and little trouble was experienced in maintaining the desired supply.

Immense quantities of fine-grained sand have collected behind Bull Sluice dam and as far up as the Roswell bridge. Sample *T-4* from a bar in the river above the dam, has a fineness modulus of 1.26 and 26 per cent coarser than 48 mesh. A still finer sand, sample *T-3*, having a fineness modulus of 1.04, has been deposited in large quantities on the banks of the river between the bridge and the dam. Sand of this type would be excellent for asphalt paving. Coarser sand has collected in the impounded stream at a considerable depth just above the dam. Rail transportation is within a half mile to the west where the Southern Railway crosses the river. Below the dam large quantities of coarse-grained sand are exposed in the stream bed.

GILMER COUNTY

No sand or gravel has been produced for shipment in Gilmer County. Most of the river sand is fine-grained and that in the creeks is coarse and composed mostly of schist and limonite particles.

Ellijay.—Sand is obtained from the bed of Cartecay River near the railroad at East Ellijay, but the material is fine-grained and suitable for brick and plaster work only. Sand from the bank of this river at the Shippers' Lumber Company, 5 miles northeast of Ellijay, was tested at the Georgia School of Technology and found to contain only 40 per cent coarser than 48 mesh. The strength of mortar made from the sand was only 40 per cent of normal. Some sand also occurs in Ellijay and Coosawattee rivers, but they are swift, and their beds are rocky. Mountain Town Creek probably has the best sand and gravel of any stream in the county. It occurs in small deposits in the stream for a distance of 5 or 6 miles above its junction with Ellijay River.

Sand from Drunkard's Spring, 1¾ miles east of Ellijay, was also tested and found to have 70 per cent coarser than 48 mesh. The strength of mortar made from this sand was only 54 per cent of normal. The sand had a large amount of organic matter also.

Licklog, Clear, and Tickanetley creeks, in the southeast part of the county, have small sand deposits suitable for any local construction work that may be undertaken.

GREENE COUNTY

No sand or gravel is shipped from Greene County.

Greensboro.—Sand supplies near Greensboro are not in large quantities nor of the highest quality. A large amount has been obtained from the W. T. Speer property, 1½ miles southeast of the town on the Siloam road. The sand here covers several acres and is from 1 to 4 feet in depth. It has been deposited partly by a small stream during heavy rains. The sand is gray, medium-grained, and has a rather high percentage of loam.

Beaverdam Creek, on the Veazey road 4 miles south of Greensboro, is 20 feet wide and from 1 to 2 feet deep and has small amounts of excellent, coarse-grained sand in its bed and along its banks. This sand has been hauled to Greensboro for local use. Sample *T-261* is typical of the sand and showed a fineness modulus of 4.05 and 99.2 per cent coarser than 48 mesh.

Areas of gray land in Greene County generally indicate underlying granite whose weathering produces a somewhat loamy sand, but suitable for most local work. Small deposits of this kind are particularly noticeable on the Union Point road, 2 miles northeast of Greensboro, on the Ward and Williams places.

GWINNETT COUNTY

The sand and gravel in Gwinnett County are restricted to the streams, and although none is produced commercially, they afford an adequate local supply for most purposes.

Lawrenceville.—One and a half miles southeast of Lawrenceville, near Ewing Mill, on Shoal Creek, deposits of coarse-grained sand, having from 25 to 50 cubic yards have been left by the creek during high water. The sand is fairly good, although it has a large amount of schist and limonite fragments. Similar patches occur at intervals along the creek, below this deposit. Similar sand is obtained for use in Lawrenceville from Wildcat Creek on the Buford road.

Duluth.—One mile north of Duluth, a small branch which has been dredged for drainage purposes, shows the following typical section in its banks:

Section of bank of Branch Creek, one mile west of Duluth

	Feet
Brown, fine-grained sand would apparently make a fair molding sand	3
Yellow, silty sand better suited for molding	2
Blue clay	3

Sections such as this are usually found in the bottom lands and along the banks of most of the streams in North Georgia. The coarse sand lies below and is at present only exposed in the bed of the stream.

Suwannee.— Suwannee Creek, about a half mile east of Suwannee, on the Lawrenceville road, at the water-pumping station, has a large quantity of coarse-grained sand and some gravel. Particles of schist and limonite make up about 25 per cent of the deposit. This sand is hauled to Buford and Suwannee and used in local construction work. Sample *T-199*, from this deposit, has a fineness modulus of 3.30 and 90 per cent is coarser than 48 mesh. The organic color value is 100. About two miles below this point on the same creek there is a large deposit of similar sand. Smaller patches having from 30 to 50 cubic yards occur along the creek to Chattahoochee River.

HABERSHAM COUNTY

No sand or gravel has been shipped from Habersham County.

Clarkesville.—Good sand is found in most of the creeks near Clarkesville. Sample *T-192* was obtained from Hazel Creek, one mile from Clarkesville on the Tallulah Falls road, and is fairly typical of the character of the sand met with through the county. It has a fineness modulus of 2.61 and 84 per cent is retained on the 48-mesh sieve. The organic color value is 200. The sand is reddish-yellow, and schist and feldspar make up 50 per cent of the particles over 14 mesh. Mica is also common in coarse flakes.

Soque River, along most of its course, is filled with a fine-grained sand of little value. Similar sand has been deposited on its banks, and very little coarse sand is found in the river except in the northern part of the county.

Chattahoochee River, on the road between Clarkesville and Helen, has a large deposit of sand and gravel. Sample *T-194*, taken from the river at this point, has a fineness modulus of 4.42 and 37 per cent is retained on the 4-mesh sieve. Similar sand and gravel occupy the bed of the river for most of its course along the western boundary of the county.

Cornelia.—Little Hazel Creek and its branches furnish an excellent natural concrete aggregate. That from Little Hazel Creek near Mount Airy has been successfully used in the construction of bridges and other concrete structures in the vicinity.

HALL COUNTY

No sand or gravel is produced commercially in Hall County.

Gainesville.—Sand used in Gainesville, and not shipped in from commercial pits, is usually obtained from small surficial deposits produced by the weathering of granitic gneiss and from gullies in which it collects after heavy rainstorms. The supply is limited to small amounts which are quickly exhausted, until more is carried down by the temporary streams. The sand is grayish-white and has a large percentage of silt. Most of the sand is obtained from the Dixon, Spain, and Finger properties, all located north of Gainesville from one to two miles on or near the Dahlonega road. Sand of this kind also occurs on the farm of the North Georgia Power Company, 1½ miles north of Gainesville. Sample *T-198*, from the last-named locality, is typical of the sand, and has a fineness modulus of 1.99 and 70 per cent is coarser than the 48-mesh sieve. The organic color value is 700 and the grains are almost entirely of angular quartz.

Chestatee River.—Ten miles west of Gainesville, on the Dawsonville road, for almost a mile above the dam at Glover's Mill, Chestatee River is filled with thousands of yards of coarse-grained, quartz sand, containing a few black particles of schist and limonite and some larger pebbles up to 1 or 2 inches in diameter. This material can easily be removed by dredging, but its distance from a railroad will prevent its utilization except for local projects. Below the dam is a bar or island containing about one acre and composed of similar coarse sand from 3 to 6 feet thick. Sample *T-197*, taken from this bar, is typical of the sand in Chestatee River from Glover's Mill to its confluence with Chattahoochee River. The sand has a fineness modulus of 3.46 and 94 per cent is coarser than 48 mesh. The organic color value is 250. Two per cent of the sand exceeds a half inch in size and the coarser particles consist of equal amounts of quartz, feldspar, schist, limonite, and mica.

Chattahoochee River, which flows through Hall County from the northwest corner to its junction with Chestatee River at the center of the western edge of the county, has a great many sand bars along its course. The sand is similar to that on Chestatee River. The bed of the river is usually composed of coarse gravel and sand similar to that above the steel bridge on the Gainesville-Dawsonville road.

HARALSON COUNTY

No sand or gravel is produced for commercial shipment in Haralson County, although adequate supplies for local purposes occur in most of the streams. The best sand and gravel are found in the streams in the southern part of the county, particularly in Walker Creek and its branches.

Big Tallapoosa River, in the northern part of the county, generally has a rocky or muddy bottom, although in places small bars of good sand have collected. At the Central of Georgia Railway crossing there is only a very small amount of sand.

HARRIS COUNTY

Except on the ridges in the northern part of Harris County, the surface is usually covered with many feet of residual clay produced from the weathering of the gneisses. No commercial sand or gravel is produced in the county, although extensive beds of quartzite, of differing degrees of purity and hardness, occur, and they may have commercial possibilities.

Hamilton.—Coarse sand of good quality for concrete, although containing 10 per cent of schist particles, occurs on the flats adjoining Mulberry Creek at Mobley's Mill, just west of the bridge on the Columbus-Hamilton road. A finer-grained sand, suitable for brick work, lies farther from the creek. Sand similar to that in Mulberry Creek is found in smaller quantities in Osahatchee Creek. Small quantities of fair sand occur in Mountain Creek northwest of Pine Mountain.

Pine Mountain Quartzite.—Pine Mountain extends across the northern part of the county from Hargett on Chattahoochee River to the Meriwether county line southwest of Warm Springs. White, gray, and yellowish quartzite, in various stages of metamorphism, composes the mountain and dips uniformly to the northwest 30° to 50°, with a strike of about N. 70° E. Oak Mountain, a much shorter and lower ridge, extending eastward from Hamilton to the county line, is composed of the same quartzite. On Oak Mountain the quartzite dips southward from 30° to 40°, indicating a simple anticlinal structure between it and Pine Mountain in this county. Layers of gneiss and schist, sometimes graphitic, are interbedded with the quartzite and may sometimes grade into it, particularly that exposed on Oak Mountain. Outcrops of the quartzite are almost continuous and very prominent on the south side of Pine Mountain, but the bed-rock is usually concealed on the north side by a mantle of fragmental quartzite, sand, and clay, except in the cuts along the new Columbus road. The quartzite has two well-defined joint systems: the one having a general northwest-southeast trend, and the other a northeast-southwest trend. The bedding planes are usually prominent, and the strata range from a fraction of an inch to 4 or 5 inches in thickness. Metamorphic action has crushed the quartzite in many places, giving it a schistose appearance as well as flattening the individual quartz grains and causing secondary crystallization. In texture, it ranges from a dense vitreous quartzite to a friable sandstone. Mica flakes, apparently of secondary origin, are common and are found in the bedding planes. Secondary quartz stringers and lenses due to recrystallization of the silica, are also found. Pyrite crystals occur through the quartzite, sometimes in considerable amounts. The quartzite ranges in color from an almost pure white to a pinkish-, or even a reddish-brown. Mica flakes and quartz crystals may give a mottled appearance to the quartzite.

At Tip Top, in a cut of the Central of Georgia Railway, the grain structure of the quartzite is plainly visible. The rock here is brittle and easily crushed, and it has been quarried and used to surface roads, as far off as Columbus. The material, however, does not appear to be well suited for road building, due to its friability. The quartzite at this point is similar to sample *T-99*, an analysis of which showed 1.10 per cent of iron oxide (Fe_2O_3).

On the south side of Pine Mountain, the quartzite exposed on the Hamilton-Copeland road, near the top, is well-bedded and dense, but it has a poorly defined grain structure. Upon crushing, such material should be suitable for the manufacture of silica brick, although it is not as dense or tough as the ganister rock used so widely in Pennsylvania for this purpose. The dip of the quartzite here is 33° to the northwest and the strike N. 42° E.

At King's Gap, 2½ miles northeast of Tip Top and on the Chipley-Shiloh road, the quartzite is well exposed, dipping to the northwest at about 38°. The material here is more thinly bedded and schistose than to the southwest and consequently not so tough or pure.

On the Shiloh-Warm Springs road, at the junction of Harris, Talbot, and Meriwether counties and on the south side of Pine Mountain, a thin-bedded, rather rotten, iron-stained quartzite, highly metamorphosed, and containing secondary quartz and mica, outcrops for several hundred feet. The rock dips 32° to the north and strikes N. 85° E. Toward the top of the ridge the dip becomes almost horizontal, and the grains become coarser and the beds thicker, although the thicker beds can be easily divided due to their friability. Two well-defined jointed systems are prominent in the exposures along this road. Partings in the quartzite about half an inch thick and separated by mica flakes occur. Quartz veins from 1 to 3 inches wide are seen in some places. Sample *T-99,* representative of the lower part of the exposure was analyzed.

Analysis of quartzite from Pine Mountain, Shiloh-Warm Springs road, T-99

Loss on ignition	1.28
Soda (Na_2O)	0.08
Potash (K_2O)	0.03
Lime (CaO)	0.00
Magnesia (MgO)	0.00
Alumina (Al_2O_3)	4.99
Ferric oxide (Fe_2O_3)	1.10
Manganous oxide (MnO)	trace
Titanium dioxide (TiO_2)	0.28
Silica (SiO_2)	92.11
Total	99.87

Although the iron content seems too high for glass manufacture, the silica per cent appears suitable for silica brick purposes, especially as it can be easily crushed. The high alumina content would reduce its melting point somewhat.

Oak Mountain.—On the Shiloh-Columbus road, on the southern slope of Oak Mountain, the quartzite outcrops for a distance of 50 feet dipping southward 36° and striking S. 85° E. A small displacement of a few hundred yards appears to have acted approximately north and south at the site of the gap. The quartzite is thinly bedded, but more vitreous and finer than the Pine Mountain variety in this county. One thousand feet further north, and separated by thinly-bedded, impure quartzite, a 20-foot exposure of the quartzite may be seen. It is more granular, more thinly bedded, and not so hard as the first outcrop. Adjoining, and underlying this exposure, badly-weathered schist may be seen. The soil of Oak Mountain has a more reddish tinge than that of Pine Mountain, so it is likely that the quartzite is more generally interbedded with schist. Sample *T-98,* taken from the south outcrop, has the following results on analysis:

Analysis of quartzite from Oak Mountain, Shiloh-Columbus road, T-98

Loss on ignition	0.54
Lime (CaO)	0.00
Magnesia (MgO)	0.00
Alumina (Al_2O_3)	1.21
Ferric oxide (Fe_2O_3)	0.55
Titanium dioxide (TiO_2)	0.19
Silica (SiO_2)	97.18
Total	99.67

The iron content is low enough to warrant the use of this material for the cheaper grades of the glass, and its physical characteristics are such as to indicate its value for refractory brick-making as well.

HART COUNTY

The contrast in the composition of the stream sands in the southern part of Hart County and those of Elbert County to the south, is notable. The granite so abundant in Elbert County is not common in southern Hart County, and the stream sands have a much larger amount of schist and limonite particles.

Hartwell.—Lightwood Log Creek, northwest of the town and on the Bowersville road near the Seaboard Air Line Railway crossing, has excellent, coarse-grained, quartz sand with some mica flakes up to a half inch in size. The sand covers the bed of the stream which is about 25 feet wide to a depth of 2 feet. Some sand has also been deposited on the banks above the stream. Sample *T-204*, taken from this stream, has a fineness modulus of 2.62 and 84 per cent is coarser than the 48-mesh sieve. The sand is used locally in Hartwell for construction purposes. The color value of the organic content is 200.

Big Cedar Creek, 3 miles from Hartwell on the Elberton road, is 15 feet wide and has frequent bars of medium- to coarse-grained sand suitable for concrete work. The value of the sand is somewhat impaired by large flakes of mica which occur up to 1 inch across, and by numerous grains of schist and some limonite. Sand extends up the creek from the Hartwell-Newburg road, but it is rather scarce for 3 miles below this road until the Dooley Ferry-Montevideo road is reached, where there is a large deposit.

Savannah River.—At Alford's bridge, Savannah River has a fine-grained sand with considerable mica. Similar sand is found along the banks of the streams, and thin strata of coarse-grained sand show in cuts along the bank. Little of this is of value for construction work.

Plenty of coarse sand is said to occupy the river bed near Stephenson's and Green's islands. Gravel usually lies on the bed rock. This is natural, since the rock is often swept clean by freshets and the coarser pebbles would be the first to be deposited by the subsiding waters.

HEARD COUNTY

No sand or gravel is produced in Heard County, although Chattahoochee River, near Franklin, and in fact, along most of its course in the county, has large amounts of good sand.

New River, in the southeast part of the county, has large amounts of excellent sand, as has its tributary, Clear Creek. South of Franklin, Snake Creek and its tributaries have smaller amounts of sand and gravel. Whitewater Creek, in the southwest part of the county, is also sandy, but Centralhatchee and most of the other creeks in the western and northern parts of the county are shoaly and the sand content small.

HENRY COUNTY

No sand or gravel has been commercially produced in Henry County.

South River.—Bars of coarse-grained sand occupy the bed of South River in a few places. The bed of the stream is generally rocky, however, and large quantities of sand are rarely met with. Sample *T-119* was obtained from a bar in South River on the Porterdale-McDonough road, and is characteristic of the sand found along this river and in the larger creeks in the eastern part of the county. It has a fineness modulus of 2.42 and 85 per cent coarser than 48 mesh.

Factory Walnut Creek, although rocky and lacking in sand in the upper part of its course, is 20 feet wide on the McDonough-Conyers road and has small bars of coarse-grained sand. Further down, and close to South River, the sand deposits in the stream bed become larger. Bars of good concrete sand containing from 10 to 200 cubic yards occur in the lower course of Cotton Creek.

In the southern part of the county, Tussaha Creek and Towaliga River have bars of good concrete sand with a larger percentage of schist and feldspar fragments than that in the streams in the northern part of the county.

JACKSON COUNTY

Sand is produced in Jackson County for local purposes, but none has been shipped.

Oconee River.—The Mulberry Fork of Oconee River at Mulberry is about 30 feet wide and not very swift. The stream bed has quartz sand with considerable schist and limonite. The sand is colored with red clay and has a large amount of twigs and leaves in it. Sample *T-201,* obtained from this stream at O'Shields bridge on the Winder-Jefferson road, has a fineness modu'us of 2.71 and 85 per cent is retained on the 48-mesh sieve. The sand has only a trace of organic matter.

Similar sand is found in Middle Oconee River, 3 miles southwest of Jefferson on the Winder road. This stream is 40 feet wide at this point and is swifter than the Mulberry Fork. The stream bottom, which is 20 feet wide, is composed of fine-grained sand with layers of coarse-grained sand and gravel. The bed of the river is mostly coarse sand and gravel with clay admixed.

Jefferson.—Both Indian and Buffalo creeks, to the south of Jefferson, although meandering, have deposited fairly large amounts of coarse-grained, white, quartz sand along their courses. Along the latter stream, near the Jefferson-Winder road, banks of it containing up to 100 cubic yards of good sand occur.

A mile and a half east of Jefferson on the Pendergast property Curry Creek, above the dam, has deposited coarse-grained, clean quartz sand which is used in local construction work at Jefferson. Sample *T-203,* from this property, has a fineness modulus of 2.63 and 84 per cent is coarser than 48 mesh. The color value of the organic matter in this sand is 100. In this same creek a good deposit of coarse-grained sand occurs a half mile below the Jefferson bridge.

JASPER COUNTY

No sand or gravel is shipped from any part of Jasper County. Ocmulgee River and the numerous streams in the county, however, should afford an adequate supply of sand for local purposes if it can be transported.

Ocmulgee River.—At Pittman's Ferry, located in a quiet stretch of the river just above a shoal, are great quantities of sand. This sand was dragged out with scrapers, screened, and used in the construction of the hydro-electric plant a short distance above. The sand is similar to that further down the river at Dames Ferry, at which point a sample was taken (see p. 317). At Goggins Ferry, both in the river bed and on the banks, there are considerable quantities of good sand.

Wise Creek, in the western part of the county, probably has more sand than any other creek in the county. Good sand in quantities sufficient for local uses is found in places in Cedar Creek in the southeast part of the county. In Mud and Hunt creeks, however, there is very little sand.

Shoal Creek, 4 miles from Monticello on the Covington road, has considerable sand in places. Foundations for bridges have shown as much as 10 to 12 feet of good coarse sand in this stream.

Mr. Jacobs, county road superintendent, has tried to use a small gasolene centrifugal pump to recover the sand from some of the creeks for use in bridge construction. He found that it did not give satisfaction in raising the sand-water mixture a distance of 12 feet without considerable loss of time. It is likely that this could have been accomplished with a more powerful or efficient engine. He was able to get 750 cubic yards of sand from a small stream over a distance of 250 yards by hand methods. The supply was about exhausted, however, when this quantity was removed.

JONES COUNTY

No sand or gravel is produced at this time in Jones County. Along the Central of Georgia Railway, 3 miles west of Griswoldville, there is a large deposit of fine-grained, gray to yellow sand, ranging in depth from 5 to 15 feet and underlain by a red, somewhat clayey sand of Eocene age.

Both forks of Commissioners' Creek, Walnut Creek, and Falling Creek have a fairly coarse sand along their courses, so that quantities from 1 to 20 carloads can be obtained near most of the road crossings of these creeks.

Ocmulgee River, forming the western boundary of the county, has an abundance of medium- to coarse-grained sand which is pumped on the opposite side of the river at Dames Ferry. Lack of transportation on the Jones County side will prohibit the use of this except for local purposes.

LINCOLN COUNTY

No sand or gravel is exploited in Lincoln County. In the northern part of the county near Goshen, and also around Pansy, considerable sand has been produced from the weathering of the underlying granite. This sand is fine- to medium-grained and is usually from 1 to 4 feet thick. Some sand occurs in the fork of Soap Creek, on the Appling road, one mile south of Lincolnton. It is coarse and composed mostly of quartz grains and is used for local purposes.

The main branch of Soap Creek, Fishing Creek, and Pistol Creek, the latter in the northern part of the county, has excellent coarse, quartz sand in quantities sufficient for local construction work or for road building.

Both Savannah River, on the eastern side of the county, and Little River on the south, are said to have muddy bottoms, or else are shoaly, with very little sand of any value. Broad River, forming the northern boundary of the county, has good, coarse-grained sand in bars containing from 10 to 200 carloads. Distance from transportation will prevent the utilization of this material.

LUMPKIN COUNTY

No sand or gravel is being produced in Lumpkin County, although the streams generally have fair-sized deposits of gravel with some sand.

Yahoola Creek, on the upper Gainesville road, has large bars of coarse sand and quartz gravel containing from 200 to 400 cubic yards each. All of the smaller branches and creeks around Dahlonega have small quantities of sand, suitable for use in local construction work. Most of the Lumpkin County streams have been dredged for gold and it has been found that the depth to bed-rock ranges from 1 to 15 feet, the upper part consisting of alternating layers of sand and muck, averaging about 3 feet in thickne s, and from 1 to 3 feet of clean, quartz gravel lying directly on the rock.

Auraria.—Etowah River, near the Dawsonville road bridge, has left a deposit of clean, coarse-grained, quartz sand about 2 acres in extent on the inside of a sharp turn in the river. The sand appears to be from 3 to 6 feet thick, and a sample of it (*T-195*) showed a fineness modulus of 2.89 and 95 per cent coarser than 48 mesh. The organic color value of the sand is 150. Six per cent of the material is retained on a half-inch sieve, and the coarser particles are mostly rather friable quartz, schist and some feldspar. Similar deposits occur along this stream, particularly on the inside of the curves.

McDUFFIE COUNTY

No sand or gravel has been produced commercially in McDuffie County. Sand hills are prominent in the southern part of the county and are an extension of those in Crawford and Taylor counties to the southwest. The sand is yellow, fine-grained and from 3 feet to 12 feet thick. No railroad, however, runs directly through this sand, so that its utilization is impossible at this time.

Boneville.—Half a mile northeast of Boneville on the Thomson-Augusta road, the northern edge of the sand belt may be seen. The yellowish-white surficial sand is from 4 to 6 feet thick and is underlain by 10 feet of coarse, red, somewhat clayey sand containing irregular, clay gravel lenses from 1 to 2 feet thick.

Thomson.—In the vicinity of Thomson small quantities of limonite gravel occur. The limonite, or iron oxide pebbles composing this material are easily crushed, and it does not make as good a road gravel as one containing tough quartz pebbles. On the Mrs. Ira Farmer place, 1½ miles from Thomson, limonite gravel appears on the surface of, or irregularly underlies, about 20 acres. It ranges in thickness from 1 to 6 feet and has a large percentage of clay. A small pit on the property has supplied road material to the county, and it has proved very satisfactory in road construction. Similar material occurs on the Hobbs farm west of the Farmer plantation.

MADISON COUNTY

No sand or gravel has been produced in Madison County. The streams, however, adequately supply the local demand for construction purposes throughout the county. Broad River, forming the eastern boundary of the county, has the largest amounts of sand of any stream in the county. A large bar above the steel bridge on the Berkely-Elberton road has over 10,000 cubic yards of excellent sand.

MERIWETHER COUNTY

No sand or gravel has been produced commercially in Meriwether County, although the streams afford abundant supplies for local purposes, at least; and the quartzite, composing Pine Mountain, when crushed might be used in the manufacture of glass or silica brick.

Pine Mountain quartzite.—A general description of the quartzite found on Pine Mountain is given under Harris County (p. 297) in this report. Except for local differences the quartzite in Meriwether County is substantially the same as that farther west. At Dunn and Stephenson gaps on Pine Mountain, one mile south of Chalybeate on the Talbotton road, quartzite outcrops mostly on the south side of the ridge. Although this locality is in Talbot County, the occurrence is similar in Meriwether County into which the ridge passes to the east and forms the county line. The bedding at this exposure ranges from 1 to 6 inches thick, with mica partings common. Some of the material is so completely recrystallized as to resemble quartz. This form is not common, and it is usually represented by boulders lying about on the hillside. The quartzite proper is usually friable and has coarse, sharp grains. The material at this point is more highly iron-stained than at any other place observed on the mountain. Sample *T-100* on analysis gave the following results:

Analysis of quartzite from Pine Mountain, 1 mile south of Chalybeate, T-100

Loss on ignition	1.19
Lime (CaO)	0.00
Magnesia (MgO)	trace
Alumina (Al_2O_3)	3.28
Ferric oxide (Fe_2O_3)	1.02
Titanium dioxide (TiO_2)	0.19
Silica (SiO_2)	94.17
Total	99.95

West of Chalybeate, Pine Mountain makes a great S-shaped swing, and the dip and strike change frequently indicating a much more complexly faulted synclinal structure than was the case further west. Three miles south of Woodbury the ridge makes almost a complete circle and encloses a relatively low, level area known as The Cove. That portion of Pine Mountain enclosing The Cove is composed of highly indurated, fine-grained quartzite. The bedding is usually thin, ranging from 1 to 2 inches, although some thicker beds occur. The quartzite is generally pinkish to reddish with limonitic and manganiferous stains when freshly broken, and considerable mica also occurs in it. The outlines of the grains are rarely distinct.

Sample *T-101,* typical of the quartzite in this part of the mountain, resembles *T-100,* and the iron content is probably about the same. Quartzite of this character should be well suited for refractory brick purposes and although more difficult to crush than some encountered further west of Pine or Oak mountains, its superior toughness would add to the quality of the product.

SAND DEPOSITS

The course of Sulphur Creek, in the southwest part of the county, has been changed due to rafting some years ago, and as a result its former bed is exposed for some distance. A very good medium- to coarse-grained sand, well suited for concrete, occurs in this old bed from White Sulphur Springs almost to Pine Mountain. The sand is at least 3 feet thick and the bed is from 8 to 20 feet wide.

At Dallas Mill, near the Troup County line and 2½ miles north of Chipley, good building sand occurs both in the mill-pond and along the creek above the mill. On a small branch of Sulphur Creek, near Williams Mills, and within a quarter mile of Cameo Station good, medium-grained sand suited for building purposes is found.

Flat Creek, on the Greenville-Hogansville road has a good medium- to coarse-grained sand in bars containing about a carload each. Further up this creek the sand increases in quantity. Sample *T-123,* from this creek, is representative of the stream sand generally found in Meriwether County and is of excellent quality. The fineness modulus is 2.63 and 94 per cent of the sand is coarser than 4 mesh. The organic color value is 50. The sand is dark brown and contains 75 per cent feldspar. Limonite grains in the material are coarser than 10 mesh.

Red Oak Creek also has good coarse sand in quantities similar to that in Flat Creek. The sand in the branch of this creek crossing the Greenville-Newnan road, 4 miles from Greenville, is a particularly good concrete sand. Some sand also occurs in Shoal Creek in the southwest part of the county in Kennal Creek, in the southern part of the county, and in Beach Creek, east of Greenville. Very little sand occurs in White Oak Creek in the northeastern part of the county.

Flint River.—Flint River has bars of good sand at a number of places along its course. The most prominent bar and the one best suited for commercial purposes, lies near the Macon & Birmingham Railway bridge, east of Woodbury. The Southern Railway crossing a few miles above also affords transportation in case sand should be pumped from the river for commercial purposes.

MILTON COUNTY

No sand or gravel has been produced on a commercial basis in Milton County. The many streams usually have a fairly good coarse-grained sand suitable for most local purposes.

Alpharetta.—The best sand close to Alpharetta, and perhaps the best in the county, occurs in bars along Sandy Cooper Creek and is particularly prominent on this creek on the Walter Thompson place. The sand has been used in concrete bridge construction in the county and has given good results. Sample *T-185*, obtained from Sandy Cooper Creek, is typical of this sand and of that in most of the creeks in the county. It has a fineness modulus of 2.64 and 83 per cent is coarser than the 48-mesh sieve. The sand is yellowish-brown and 3 per cent is coarser than a half inch.

Considerable coarse-grained sand occupies the bed of Four-Killer Creek, but it is composed largely of schist particles and fragments of hornblende and limonite, so that it is not so desirable for concrete work as one containing a larger amount of quartz.

Large quantities of sand are found in the bars along Willeo Creek, but the softness of the schist and limonite particles which make up a large percentage of it, detracts from its value somewhat although it is a fairly good concrete sand.

Sand occurs at intervals along Big Creek, and, although the quantities are not so large as in the other creeks mentioned, the sand is of better quality than that in most of them except Sandy Cooper Creek.

MONROE COUNTY

In Monroe County sand is pumped for shipment from Ocmulgee River at Dames Ferry. Smaller deposits of sand are found in the creeks in practically all parts of the county.

Ocmulgee River.—Ocmulgee River forms part of the eastern boundary of Monroe County and is an inexhaustible source of good, medium- to coarse-grained sand. The Southern Railway runs along the west bank of the river through the county, so that transportation facilities are ideal.

Smiley Sand Company.—The Smiley Sand Company, of Atlanta, operates a 6-inch Morris centrifugal pump, on the west bank of Ocmulgee River, 1,200 yards north of Dames Ferry railroad station. The sand is washed through a half-inch screen to remove twigs and foreign material directly into the freight car, and the water and silt drains off through the cracks in the car. By this method it is possible to fill a car in less than an hour, although such speed is rarely attained. The river at this point was about 2 or 3 feet deep before pumping was commenced, and is from 4 to 25 feet deep when bed-rock is reached. A dam across the river a short distance below the pump backs the water up and causes the deposition of considerable sand. This factor, together with the close railroad connections, makes the spot an ideal one for economical sand production. A little over a mile above the pump the river is shoaly. Low water does not materially influence the amount of sand that may be produced; high water, however, is likely to sweep the bottom clean of sand and it may be necessary to wait a day or two after severe storms for the river to replenish the supply. When visited in June, 1920, 160 feet of 6-inch pipe were required from the pump to the railroad car. The sand has been pumped by a 25-horsepower engine, which is in use at present, a maximum distance of 368 feet. Something over 4 carloads of sand can be pumped with one ton of coal.

Sample *T-7,* taken from a loaded car, is fairly typical of the river sand at this point, after the dirt has been drained off in the water. It shows a fineness modulus of 2.21 and 93 per cent coarser than 48 mesh. The organic color value is 20. The sand is light brown and composed mostly of quartz and about 5 per cent of feldspar, mica, and limonite grains. Concrete strength ratio tests made by Prof. F. C. Snow at the Georgia School of Technology showed 104 and 100 per cent of normal at 7 and 28 days, respectively.

The first terrace above Ocmulgee River, from 200 to 300 feet wide, is underlain by considerable sand of differing degrees of fineness. A well at the Smiley pump at Dames Ferry is 15 feet deep and encounters a fine to medium-grained sand for its entire depth.

At Pope's Ferry, a few miles below, bank sand was formerly mined and shipped. The deposit proved small and variable, so that it has not paid to continue its operation.

The impounded river above the dam at Juliette should have considerable sand in its bed, and the proximity of rail transportation might indicate that this would be a favorable place for sand pumping. It is to be remembered, however, that even a river as large as Ocmulgee River above Macon is deceptive in the quantity of sand it is capable of supplying, and, unless conditions are right for the rapid accumulation of sand after its exhaustion by pumping, or when removed by a freshet, a constant supply of more than two or three cars a day can not be depended on.

Rum Creek.—Four and a half miles from Forsyth on the Juliette road, Rum Creek has small bars of coarse, brown sand, from 3 to 5 feet deep and underlain by yellow clay. The stream is rapid, and sand is moving constantly in the bed, so that the stream should afford a sufficient supply for local construction work.

Big Tobesofkee Creek.—Fairly large quantities of coarse sand well suited for concrete work occur in Big Tobesofkee Creek. Similar sand occurs in Little Tobesofkee Creek and in Echeconnee Creek in the southwest part of the county. The Macon & Birmingham Railway parallels the latter stream for some distance, affording transportation facilities.

Towaliga River.—Six miles north of Forsyth on the Jackson road, large quantities of sand occur in Towaliga River, which has a bed 40 or 50 feet wide at this point. A large dam, some distance above, causes sand to collect in the impounded river above it, and when the dam is opened twice weekly, the sand is brought down and deposited in bars, containing many carloads, to a distance of 10 or 15 miles below the dam. When the dam is closed these bars are exposed in the stream bed.

Both Eightmile Creek, on the Upper Jackson road, 8 miles from Forsyth, which is 15 feet wide, and a smaller creek, two miles beyond, and 8 feet wide, have good, coarse, concrete sand, suitable for local uses.

MORGAN COUNTY

No sand or gravel is produced in Morgan County, although the streams usually have sufficient for local purposes if the recovery and transportation cost are not too great.

Appalachee River.—Appalachee River, which separates Morgan and Oconee counties, is generally shoaly with only small quantities of sand. What sand there is in it, however, is coarse-grained and well suited for concrete. A bar having probably 50 carloads occurs just above the bridge on the Watkinsville-Madison road. At Head's Mill a large amount of good sand exists in bars close to the mill.

Hard Labor Creek.—Hard Labor Creek, where it crosses the Watkinsville road, 4 miles north of Madison, is 25 feet wide and has bars of coarse sand having a large percentage of schist and other particles of soft material. The bars on the inside of the curves near here have from 10 to 20 cubic yards of sand. Sample *T-113,* taken from the creek on the Watkinsville road, shows a fineness modulus of 3.09 and 98 per cent coarser than 48 mesh. The organic color value is 150. Tensile strength tests of the sand from the Chambers property at the Bostwick-Oil Mill road where a pump was installed showed over 100 per cent of standard Ottawa sand. The sand is dark reddish-brown. Quartz makes up the finer-grained portion of the sand, and about 10 per cent each of coarse limonite and feldspar grains occur in the sand.

To supply sand for the Federal Aid road construction in Morgan County, the MacDougald Construction Company installed a 6-inch Morris centrifugal pump, run by a 20-horsepower steam engine, in Hard Labor Creek at its intersection with the Bostwick-Oil Mill road on the Chambers property about 4½ miles northwest of Madison. The creek at this point is about 25 feet wide, and the sand ranges from 3 to 10 feet in depth. Red and blue clay underlie the sand, and sometimes a layer of coarse, white sand from 6 inches to 2 feet thick occurs beneath the clay and lies directly on bed-rock. When visited in June, 1920, the pump had been in operation 60 days, and the daily production averaged two carloads. About 200 feet of the stream bed had been cleaned of sand during this time, and the intake was located 40 feet from the discharge which was 15 feet above the intake. The sand was pumped directly into 3-ton trucks which transported the sand 4 miles to a stockpile near the construction work. The water, draining from the pumped sand, together with the heavy trucks, kept the road in bad condition. At a steep hill just south of the creek and a quarter mile long, a tractor was used to pull the trucks up.

Further down the creek on the Judge Baldwin place and near the Middle Appalachee road, there is a large bar which could supply over 1,000 cubic yards of good, coarse-grained, concrete sand. The stream here is about 35 feet wide, and the deposit is probably the best in the county.

Madison.—The local sand supply for Madison is obtained from the old stream bed of a small branch, 3 miles east of the town. This sand is of very good quality. A sample was tested at the Georgia School of Technology and found to have a fineness modulus of 2.80 and 98 per cent coarser than 48 mesh. It gave concrete having 99 per cent strength of normal.

Two small branches, just north of Madison on the Athens road, and about 6 feet wide, have small quantities of good sand, which could be used for local road construction purposes.

Rutledge.—Two miles from Rutledge on Rocky Creek, near the mill, there is a considerable amount of coarse-grained concrete sand suitable for local use.

Richland and Sandy creeks, in the northern part of the county, are both about 30 feet wide and have bars of from 10 to 40 cubic yards of brown sand with numerous schist and mica particles and also angular rock fragments. There is very little sand in the southern part of the county.

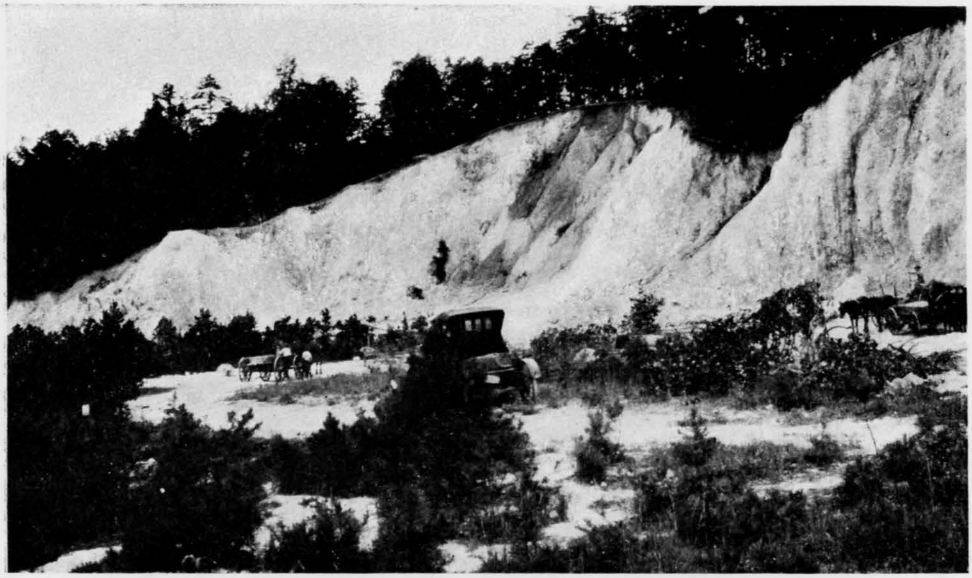
NEWTON COUNTY

Molding sand is shipped from pits along Yellow River, near Almon in Newton County. Coarse, quartz sand, suitable for concrete, may be obtained for local use in Covington in small amounts from the bed and along the banks of a small tributary of Yellow River which flows through the west part of the town. The streams in the eastern part of the county, including Alcovy River, usually have a fine-grained sand with considerable mud admixed and hence not desirable for concrete. A few local bars in these streams, however, have a coarse-grained sand with schist fragments in it.

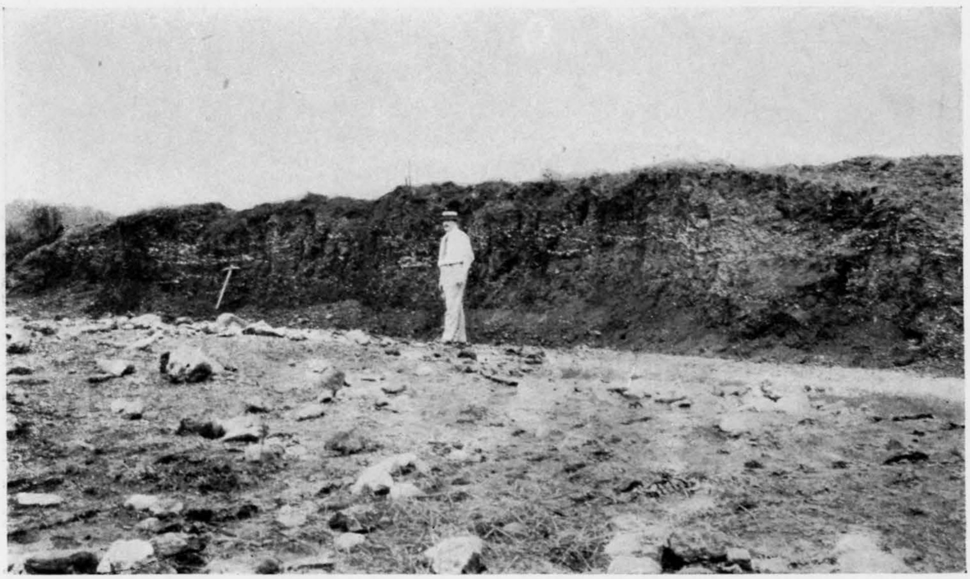
Yellow River Molding Sand Company.—Fine-grained molding sand is shipped from pits on the property of C. K. Gailey of Conyers, located one mile southeast of Almon on the west bank of Yellow River. The sand occupies a narrow belt on the first terrace above the stream on both sides of the river. The pits have been operated since 1900 and are about 300 feet west of the public road. (Plate XVII-B.)

General section at Yellow River Molding Sand Company's pits, Almon

	Feet
Gray, silty soil	1–2
Dark gray, fine-grained, loamy sand	1–3
Yellow to reddish, clayey, molding sand	1–5
Gray, fine-grained, micaceous, quartz sand	10



A. CHERT PIT, H. K. BITTINGS PROPERTY, 1 MILE SOUTH OF SUMMERVILLE. CHATTOOGA COUNTY



B. GRAVEL PIT, H. A. DEAN PROPERTY, BLACK BLUFF ROAD, 1 MILE SOUTHWEST OF ROME, FLOYD COUNTY

The soil and upper silty sand is removed by drag scrapers and the exposed molding sand is then ploughed up and later put into piles by the scraper. The sand is hauled to the railroad at Almon in wagons where it is transferred to cars. The sand usually becomes very hard on exposure to air, and it must therefore be broken up into small pieces before shipping. Sample *T-120* represents the upper silty cover, while sample *T-121* is typical of the yellow sand which is shipped.

No stratification is apparent in the sand, although it probably represents old flood deposits of Yellow River. Irregularities in the upper surface of the coarser sand below the molding sand cause the latter to thin out and become more sandy in places. Usually, however, the molding sand is fairly uniform and pits of from an eighth of an acre to an acre in extent are possible. The sand is shipped principally to Atlanta and Columbus foundries, but small quantities are also sold in Augusta, Macon, Savannah, Brunswick, and Greenville, S. C.

Sand somewhat similar to that on the Gailey property is found along the river in less well situated places with respect to transportation. The Dobbs property and the Mabert property adjoining the Gailey place, and lying along the river, have deposits of good molding sand also.

Porterdale.—A remnant of yellow, fine-grained sand and reddish-brown clay, that appears to be of Satilla or Okefenokee age, occupies a smaller area on the highest terrace overlooking Yellow River from the east. The sand attains a maximum of 10 feet in thickness on the Covington road at Porterdale and extends northwestward to the Central of Georgia Railway where it is thinner and underlain by a red clay sand.

Section on Central of Georgia Railway at Porterdale, south end of cut, northeast of power house

	Feet
Yellow, fine-grained, quartz sand, fairly clean	2
Red sand	3
Coarse, red, clayey sand	5
Clay and molding sand	5

Further north, in this same cut, from 10 to 15 feet of yellow to red clayey sand, suitable for the molding of large castings, occur. To the southwest, 5 to 7 feet of fine-grained, silty sand occur suitable for the molding of small castings.

On the spur track leading to the power-house 10 to 12 feet of medium-grained, red, clayey sand, apparently suitable for molding, is found. Sample *T-118* was taken from the cut on the Covington road at Porterdale and is representative of the fine-grained brick sand found along the upper terrace of Yellow River. It has a fineness modulus of 1.75 and 7.0 per cent is retained on the 48-mesh screen. It is yellow and composed of iron-stained quartz grains. The organic color value is 100.

In the bottom lands along Yellow River in this vicinity, a fine-grained brown sand apparently suitable for molding occurs. It ranges from 2 to 6 feet thick and is usually underlain by a coarser sand and overlain by a yellowish, silty clay a foot or two thick.

BUILDING SAND

Large quantities of medium-grained quartz sand suitable for concrete, brick and plaster work occur at the surface on the Gailey property, between the molding sand pits and Yellow River and also between the pits and the Augusta road. (Plate XVIII-A.) This sand has been shipped in small amounts.

A finer-grained sand is found close to the river bank along most of its course. It is most prominent about a mile north of Almon, just south of the first wagon bridge across Yellow River above the railroad bridge. Sample *T-121 A* shows a fineness modulus of 1.41 and 44 per cent coarser than 48 mesh. The organic matter color value is 300. The sand is from 3 to 8 feet thick and occupies several acres along the river bank.

In the western part of the county, small, coarse-grained sand deposits occur in most of the creeks. Larger deposits occur in the quieter reaches of South River, which separates Newton County from Henry County on the southwest. This stream is generally shoaly, however, and little opportunity is afforded for the accumulation of sand.

OCONEE COUNTY

No sand is produced in Oconee County, although the streams usually have sufficient for local purposes.

Town Creek.—Just north of Watkinsville, on the Athens road, Town Creek is about 15 feet wide, and has a high-grade, coarse-grained concrete sand in fair amounts, sufficient for local construction work. Sample *T-112*, taken from this creek on the Athens road, is typical of the stream sand in Oconee County and the southern part of Clarke County. It has a fineness modulus of 3.23 and 97 per cent is retained on the 48-mesh screen. It has only a trace of organic matter. The sand is dark brown and contains about 75 to 80 per cent quartz particles and the rest feldspar and schist.

Appalachee River.—Appalachee River, separating Oconee County from Morgan and Walton counties on the southwest, has widely-separated bars of sand in its bed. This sand is usually medium- to coarse-grained and composed mostly of quartz. (Plate XVIII-B.)

OGLETHORPE COUNTY

Like many other north Georgia counties, sand in quantities suitable for most local work occurs in the streams of Oglethorpe County, but at no point is there a combination of sufficient sand and convenient transportation to warrant commercial development.

Oconee River, forming part of the western boundary of the county probably has more sand than any other stream in the county. The sand is medium- to coarse-grained and well suited for concrete work.

Long Creek.—Long Creek in the eastern part of the county, where the Lexington-Tignall road crosses it, is 30 feet wide and has a 60-foot bed in which is a large amount of fairly good sand. Sample *T-114*, taken from this creek, is representative of most of the creek sand in the county and has a fineness modulus of 2.76 and 82 per cent is coarser than 48 mesh. The organic color value is 100. The sand is reddish-brown and has 2 per cent coarser than a half inch. The grains coarser than 10 mesh contain about 15 per cent feldspar, but most of the sand is clay-stained quartz and a little mica.

PAULDING COUNTY

No sand or gravel is produced in Paulding County. That for local purposes is easily obtained from the numerous streams.

Pumpkinvine Creek and its branches, near Dallas, have fair quantities of coarse- and medium-grained sand which is used locally in the town.

Sweetwater Creek, in the southeast part of the county, has large amounts of good, quartz, concrete sand, sufficient for any local construction or road work.

PIKE COUNTY

Granite is particularly prominent in the northwest and eastern portion of Pike County where its weathering has produced thin deposits of sand. No commercial sand or gravel is mined in the county, although creeks could furnish adequate local supplies, and the quartzite of Pine Mountain is available for use in silica-brick manufacture.

Little Towaliga River.—North of Barnesville, Little Towaliga River has bars of good concrete sand along its course, containing from one to three carloads each. Where the valley of the stream widens out deposits of a finer-grained sand, better suited for brick or plaster work, occur. These deposits may have from a few wagon-loads to several carloads of sand.

In the vicinity of Milner, weathering of the underlying granite has covered large areas with sand. The depth is usually small and the quality not high-grade, but it should serve for local purposes not requiring a good quality of sand.

Potato Creek.—Potato Creek, in the southern part of the county, has small sand deposits, and Elkins Creek in the southwest part also has good concrete sand in small quantities.

QUARTZITE

Pine Mountain, in Pike County, is composed of a number of hills and ridges. Its structure is more complex than in Harris County, although not so much so as in Meriwether and Upson counties. The quartzite is usually friable and fairly pure. It dips generally to the northwest from 25° to 65°, and the strike, where the Del Rey-Zebulon road crosses the ridge, is N. 25° E. A sample (*T-106*), taken near the top of the ridge on the south side, showed a friable, gray to pale-yellowish rock. No analysis was made, but the iron content is probably about the same as that found in samples taken further west and described under Harris and Meriwether counties. The friability of the rock will permit of easy grinding, and hence its use in the manufacture of silica brick is suggested. It is, of course, much too brittle for road material.

PUTNAM COUNTY

A belt of granite and intrusive granite gneisses occupies the central and some of the eastern part of Putnam county, and their weathering has produced thin deposits of sand. No sand or gravel is produced for shipment in the county. In the western part of the county, the creeks are usually small and muddy and have very little sand, which is usually of an inferior quality. Little River, however, has considerable coarse sand suitable for concrete purposes. Where the Monticello-Eatonton road crosses this stream the water has backed up, owing to a dam a short distance below, and plenty of sand is reported in the river bed near here Below the dam, sand bars, each containing many carloads of good sand, are exposed.

Hudson Creek, just west of Eatonton, has fairly large quantities of sand which is hauled to Eatonton and used locally. It has been found more desirable, however, in the larger buildings, to have sand shipped in from Macon or other points.

Four miles from Eatonton, on the Sparta road, and on the adjoining plantation roads, up to 4 feet of gray, medium-grained sand may be seen. Since most of this part of the county is underlain by granite, the sand probably represents a weathering product. Its quality is rather poor and the quantity usually small.

Crooked Creek, where it is crossed by the Sparta-Eatonton road, 5½ miles from Eatonton, is about 6 feet wide and has bars along its course containing about 15 cubic yards each.

Oconee River.—On the terraces paralleling Oconee River, the quantity of sand is small and it is usually fine-grained. Considerable sand occupies the bed of the river, however, where it is not too shoaly. No transportation facilities exist along the river, hence the utilization of the sand is impracticable except for construction purposes within a short distance.

RABUN COUNTY

No sand or gravel is produced commercially in Rabun County. Dicks Creek, on the road from Dicks Creek Gap to Benton, has small bars of excellent sand and gravel from the foot of the mountain to Tallulah River. The sand is of especially good quality for the first one or two miles above the river.

Tallulah River.—Fine- and coarse-grained sands are found in Tallulah River in the quiet reaches between the shoals. A large deposit of white, fine-grained sand occupies the banks of the stream from the bridge below Wiley almost to the dam. The sand, although too fine for concrete, is suitable for brick work and is from 3 to 6 feet thick, extending for a half mile with interruptions along the west bank. The belt is from 300 to 500 feet wide.

Probably the best sand in the county is found along Timpson Creek, from Tallulah River to a point 5 miles above. Deposits of several hundred, and even thousands, of cubic yards of clean, coarse-grained, gray, quartz sand occupy the bed of the stream or occur along the bank.

Clayton.—Sand from Stekoa Creek, just east of the dam, is used locally. Sample *T-189*, obtained from this creek, near the Tullalah Falls road, a mile south of Clayton, was found to have a fineness modulus of 2.59 and 76 per cent coarser than 48 mesh. Tiger Creek has large quantities of good, coarse-grained, white sand along most of its course. The organic matter color value is 400, and the sand is reddish-yellow. Ten per cent of the material exceeds half an inch in size. The coarser particles are made up of 25 per cent quartz, and the rest is schist and feldspar. Considerable medium-grained, limonite also occurs in the sand. In 1912 it was dammed on the Betterfield place and considerable sand collected in a pond. This sand was used largely in the construction of the dam and the hydroelectric plant on Tallulah River at Tallulah Falls.

ROCKDALE COUNTY

Small quantities of coarse-grained, concrete sand occupy the beds of most of the creeks of Rockdale County, particularly Big Haynes Creek, although no deposits occur sufficiently large for commercial pumping. Sand in much larger quantities, although finer-grained occurs in bars in South River. The sand in Yellow River is rather finer-grained, but along its banks immense quantities have been deposited in the latter part of 1919 by freshets. This sand is yellow, medium-grained, and of good quality and occurs along the river almost for its entire course in the county. The sand is particularly prominent along the river 4 miles northeast of Conyers.

SPALDING COUNTY

No commercial sand or gravel is produced in Spalding County, although streams have many small deposits sufficient for local purposes and for road building.

Phillips property.—A small stream running through the E. L. Phillips' property, 3 miles south of Griffin, has considerable coarse-grained sand, about 10 per cent of which is composed of schist, feldspar, and limonite grains, so that the sand is brown. Some gravel is associated with the sand in bars in the creek channel, and gravel usually underlies the sand at a depth of one to two feet. In places the sand completely fills the stream channel to a depth of 5 feet, so that several carloads could be obtained in one spot. Sample *T-107*, from this stream, is typical of the stream sands found throughout the county, and it shows a fineness modulus of 3.55 and 95 per cent retained on the 48-mesh screen. The color value, due to organic matter, is 100.

Flynt property.—Three miles north of Griffin, on the Mount Zion road, a small stream has deposited a little coarse sand along its course. A mile east of the road, on the Frank Flynt property, the stream channel is from 5 to 7 feet wide, and sand well suited for concrete purposes occurs from 3 to 4 feet thick in the creek and stream bottom and is underlain by blue mud. The flow of the water is as strong as in the Phillips' branch, but the quantity of sand not so great, however, it should be sufficient for local concrete construction. Sample *T-108* showed a fineness modulus of 2.41 and 76 per cent coarser than the 48-mesh screen. The organic matter color value is 100.

Flint River.—Flint River, forming the western boundary of the county, has small bars of medium- to coarse-grained brown sand. The quantity and the stream flow appear to be sufficient to warrant the installation of pumps at either the Southern or the Central of Georgia railway crossings, should there be a demand. In the northern part of the county Cabin Creek and Towaliga River have good deposits of coarse sand and gravel.

Sand of good quality is general in the larger streams throughout the county. None occurs in quantities sufficiently large for commercial purposes, but the deposits can supply most local demands.

STEPHENS COUNTY

No sand or gravel is shipped from Stephens County.

Tugaloo River.—Sand from Tugaloo River was used in the construction of the Southern Railway bridge and has proven to be of excellent quality. Bars containing from 100 to several thousand cubic yards of sand occupy the bed of the stream at a number of points. The sand near the Southern Railway bridge is most conveniently suited for shipment, although difficult to recover.

North Broad River.—North Broad River generally has large amounts of coarse-grained sand in its bed southward from Dick's

Hill road, and the sand is from 2 to 4 feet thick. Sample *T-193* from this point is typical of the Broad River sand and has a fineness modulus of 1.93 and 67 per cent coarser than 48 mesh. The organic color value is 100.

TALLIAFERRO COUNTY

No sand or gravel is shipped from Talliaferro County, and their occurrence is limited principally to the streams. A mile and a half northeast of Crawfordsville on the Washington road, a small branch from 5 to 7 feet wide, has small quantities of coarse sand with about 10 per cent of schist particles. The sand is hauled to Crawfordsville and used for local purposes.

On the Powelton road, Ogeechee River is from 10 to 15 feet wide, and has small bars of sand. The sand is brown and medium- to coarse-grained and could be used for local road construction. A branch of Ogeechee River, crossed on the Powelton road 2½ miles north of Powelton, has considerable sub-angular to angular gravel.

Little River.—Little River, which forms the northern boundary of Talliaferro County, has bars of fairly good concrete sand along its course. At low water when they are exposed they should yield from 10 to 100 carloads each.

TOWNS COUNTY

No sand or gravel has been produced in Towns County. Many of the streams have small deposits of coarse-grained sand of good quality. Deposits of quartz are also known in the county, the most prominent one of which is that on Bell Mountain, near Hiwassee.

Hiwassee.—Hog Creek, two miles from Hiwassee on the Clayton road, has bars with from 40 to 400 cubic yards of coarse sand and gravel along its course. Sample *T-188* showed a fineness modulus of 1.56 and 58 per cent coarser than 4 mesh. This material contains about 8 per cent clay, and the pebbles are mostly of quartz.

Hiwassee River.—From a point about 4 miles southeast of Hiwassee, Hiwassee River has a rocky bottom with little sand. From Mountain Scene southward, the stream has small bars of very good concrete aggregate.

Bell, Mill, Scattaway, and Cabin creeks have small bars of from 5 to 25 cubic yards of good sand and gravel. Bell Creek, in the northern part of the county, has good sand, and Hightower Creek, in the northeast section, has small bars of fairly good sand and gravel.

QUARTZITE

Two miles north of Hiwassee the highest peak of Bell Mountain is composed of heavy bedded white quartz which grades into a more impure granular quartzite. The east face of the mountain is made up of the glistening, steeply dipping rock which makes a prominent landmark visible for many miles.

The peak of the mountain consists of a quartz injection, which is heavily bedded and has the appearance of a sedimentary formation. The quartz dips 42° to the northwest and strikes N. 25° E. Beneath the quartz is a hornblende schist and above it a garnetiferous rock that may be intrusive. The upper part of the quartz is the purest, usually of snow white, only a few ferruginous stains running irregularly through the white material. Samples of this purer quartz (*T-190*) and the stained quarts (*T-191*) were analyzed.

Analyses of quartz from highest peak of Bell Mountain, Hiwassee

Constituents	T-190	T-191
Moisture at 100 °C	0.00	0.03
Loss on ignition	0.00	0.19
Ferric oxide (Fe_2O_3)	0.12	0.38
Manganous oxide (MnO)	0.00	0.56
Silica (SiO_2)	99.85	98.78
Total	99.97	99.94

This material is suitable for glass, or other uses to which high-grade silica is put, but its inaccessibility would eliminate it for this purpose. Its use in lining furnaces and for flux is also suggested.

Further down the mountain, on the north side, the material becomes granular and even friable, with a yellowish or brownish tint due to a rapid increase in the iron content.

TROUP COUNTY

No sand is produced commercially in Troup County. The creeks afford plenty for local purposes, and although such sand is usually coarse-grained most of it has considerable mud, which should be washed out.

La Grange.—On the La Grange-Hogansville road, Shoal Creek is about 40 feet wide and rather sluggish. An acre or two of coarse-grained sand, from 1 to 4 feet thick and having pebbles and mud balls in it, has been deposited in the fields on the left bank of the stream. Sample *T-125*, taken from this deposit, has a fineness modulus of 3.20 and 97 per cent is coarser than the 48-mesh sieve. The organic matter color value is 60. The sand is dark reddish-brown and contains 3 per cent coarser than a half inch. Seventy-five per cent of the material coarser than 35 mesh is composed of limonite and feldspar.

Beach Creek, on the same road, has small bars of dark brown sand. A smaller stream, 3½ miles south of Hogansville, has deposited several acres of silty sand along its course near this road.

Hogansville.—Four miles south of Grantville, on the Hogansville road, a small stream has deposited several acres of excellent coarse-grained, concrete sand. The deposit adjoins the Atlanta & West Point Railroad and is probably only from 1 to 3 feet thick.

Yellowjacket Creek, one mile north of Hogansville, is 15 feet wide and has numerous sand bars with from 25 to 200 cubic yards of sand.

A small deposit of good, medium-grained sand occurs west of the railroad, in Hogansville, along a small branch. About a mile west of Hogansville, on the Levius Wood place, several acres near a small creek are covered with good sand to a depth of 1 to 3 feet.

Long Cane and Blue John creeks in the southwest part of the county are sluggish. Their bottoms are composed mostly of mud and clay with rarely a poor, muddy sand. Further to the northeast, however, these streams become more rapid and fine- to medium-grained sand is deposited. Bars of medium-grained sand having from 5 to 20 cubic yards each occur on Blue John Creek near the La Grange-Chipley road, 2 miles south of La Grange. Long Cane Creek, further south on this road, is larger, and the sand is not so prominent, although it occurs in the stream bed.

Mud Creek, on the La Grange-Chipley road, 10 miles from La Grange, is 10 feet wide and has many bars of good medium- to coarse-grained sand of from 25 to 100 cubic yards each. Some pebbles up to 1½ inches in size occur in the sand. Sample *T-124*, from this creek, has a fineness modulus of 2.54, and 89 per cent is retained on the 48-mesh screen. The organic color value is 150. The sand is yellowish-brown, and 75 per cent of the material coarser than 6 mesh is feldspar, limonite, or schist.

Chattahoochee River at Glass' Bridge is shoaly, but a short distance above the bridge the bed becomes sandy. A small creek on the west side of the river has good, medium-grained, yellow quartz sand, which has been used in construction work at this bridge.

Gravel.—Thin beds of clay gravel occur in places on the upper terrace overlooking Chattahoochee River. They are particularly prominent opposite West Point on the Alabama side, but here they rarely exceed 2 or 3 feet in thickness. In the first bottom of Chattahoochee River at West Point, wells have encountered alternating layers of silt, sand, and gravel to a depth of 50 feet where the solid crystalline rock is reached. It is likely that most of the gravel in the river bottoms has too much overburden to warrant mining, but a detailed investigation of the wells drilled or dug along the river may disclose favorable gravel-bearing areas.

UNION COUNTY

No sand or gravel has been produced in Union County. The streams have deposits of coarse-grained sand containing a considerable percentage of softer minerals, but most of it is suitable for construction purposes.

Young Cane Creek, in the southwest part of the county, has bars of fairly good, coarse-grained sand, suitable for local work, although it contains 20 per cent or more of mica and schist fragments.

Nottely River, south of Blairsville, has a rock bottom with large boulders and considerable mud and silt. Some fine-grained sand, however, has been deposited at a few places in small quantities in this vicinity.

Fairly good sand and gravel are found in Coosa Creek, a tributary of Nottely River, 3 miles south of Blairsville, and in Butternut Creek, one mile northeast of Blairsville on the Hiwassee road. The latter creek is 18 feet wide and has small bars of very good sand and gravel. Sample *T-187* has a fineness modulus of 4.55, and 46 per cent is retained on the 4-mesh sieve. Sub-angular quartz makes up 80 per cent of this material, and schist and feldspar particles compose the rest.

UPSON COUNTY

No sand or gravel is produced commercially in Upson County, although large amounts occur in Flint River and its tributary streams, and large deposits of quartzite, suitable in some places for the cheaper grades of glass and for the manufacture of silica brick, are found in Pine Mountain in the southwest part of the county.

Flint River.—Bars of excellent medium- to coarse-grained sand, suitable for concrete purposes, are found in Flint River at a number of places along its course. The most prominent bar and the one best located from the transportaiton standpoint is found at the Macon & Birmingham Railway crossing in the northwest part of the county.

At Barker's Springs, one mile east of Crest on the Macon & Birmingham Railway, a small branch has good sand in quantities sufficient for local uses.

Colquitt property.—Sand is hauled from the bed of Potato Creek and from its banks on the Colquitt property to Thomaston, 2 miles distant, for local use in concrete work. The best deposit is near the railroad bridge and about a mile north of the Woodbury-Thomaston road. The sand is gray to brown, medium-grained, and contains 5 per cent of schist, feldspar and minerals other than quartz. The quantity is sufficient to easily supply all local demands.

Little Potato Creek.—No sand of any value was seen between Thomaston and Yatesville except on Little Potato Creek, which is a fairly large, rocky stream that has been dammed at the Thomaston-Yatesville road. Some sand has collected above the dam, and a sample of it (*T-104*) showed a fineness modulus of 2.35 and 81 per cent coarser than the 48-mesh sieve. The sand has only a trace of organic matter and is reddish-brown. The particles are clay-coated quartz and feldspar. Further back from the stream, the sand is finer-grained; the sample, however, is typical of the stream sand encountered in Upson County.

On the Yatesville-Zebulon road some sand is found in Potato Creek near Del Rey, similar to the sand in this same creek further south.

QUARTZITE

Pine Mountain extends into the southwest corner of the county and runs along the western county line north to the Pike County line. It is made up of thin- to medium-bedded quartzite somewhat similar to, although denser than, the quartzite found in the mountain in Meriwether and Harris counties to the west. No samples of this rock were taken in Upson County, but the reader is referred to a detailed account of its occurrence, together with chemical analyses of the material from the western part of the ridge, described under Harris and Meriwether counties. (See pages 297 and 306.)

WALTON COUNTY

No sand or gravel is produced commercially in Walton County, although the numerous streams have abundant material for all local uses.

Many of the streams of the county have been dredged for drainage purposes, and as a result large quantities of fairly good sand have been deposited on their banks. This is particularly true of Alcovy River, where the sand is finer-grained than is desirable for concrete, but apparently suitable for asphalt construction.

Big Flat Creek, which is about 25 feet wide on the Monroe-Jersey road, has been partly dredged, and the sand taken from the river is fine-grained. Little Flat Creek has also been dredged. The sand being deposited in the deepened channel is much coarser and cleaner than that removed in dredging. The increased velocity of the current in the dredged streams prevents the deposition of the finer sand grains and mud and insures a much higher grade of sand in the stream beds. In Little Flat Creek the sand content is about 3 cubic yards for each running foot. A sample (*T-116*), taken from the stream on the Jersey road has a fineness modulus of 2.14, and 72 per cent is retained on the 48-mesh screen.

A heavy black sand which collects in ridges at the bottom of the creek is especially noticeable, and an analysis of a concentrated portion of this sand showed the black mineral to be ilmenite ($FeTiO_3$). Similarly appearing black sand is fairly common in the beds of most North Georgia streams, and it is likely that the black mineral in most cases is ilmenite.

Analysis of concentrated black sand in Little Flat Creek, Walton County

Loss on ignition	0.15
Soda (Na_2O)	0.10
Potash (K_2O)	1.28
Lime (CaO)	0.00
Magnesia (MgO)	0.16
Alumina (Al_2O_3)	5.15
Ferric oxide (Fe_2O_3)	9.49
Ferrous oxide (FeO)	11.29
Manganous oxide (MnO)	0.80
Titanium dioxide (TiO_2)	15.36
Silica (SiO_2)	55.46
Rarer earths	0.00
Total	99.60

Appalachee River, forming part of the northeast margin of the county, usually has bars of coarse-grained sand suitable for concrete work.

QUARTZITE

Alcovy Mountain, 5 miles south-southwest of Monroe, rises almost 350 feet above the general level. It is composed entirely of a highly crystalline quartzite, which appears to be largely a secondary material produced by solution and subsequent crystallization of the original sandstone or quartzite. No analysis of the quartzite was made, but it does not appear to be pure enough for any but the cheapest grades of glass. Its use in silica-brick manufacture, and as a flux, is also suggested, but its remoteness from transportation will prevent its utilization for a long time.

WARREN COUNTY

No sand or gravel deposits are worked commercially at present in Warren County, although at Norris Crossing a number of years ago, a gravel deposit was utilized for ballast purposes. A few miles south of Warrenton extensive gravel deposits are found directly overlying the crystalline basement rocks.

Carr property.—At Norris Crossing on the Georgia Railroad, four miles from Warrenton, considerable gravel occurs on the old Carr property. A pit, opened by the Georgia Railroad a quarter mile south of the railroad on 43 acres purchased from Mrs. Carr and worked for about 10 years prior to 1912, shows a face 1,500 feet long and is from 100 to 200 feet broad. The gravel in the face ranges from 4 to 6 feet in depth and is underlain by sandy clay. Sample *T-55*, from this pit, is a sandy clay gravel of which 77 per cent passes a 4-mesh screen and which has a fineness modulus of 6.74. The pebbles are usually badly weathered and rotten, particularly the granular quartz, and they can easily be broken with a hammer.

A well at Norris Crossing, 20 feet above the railroad and 500 feet north of it, shows 8 feet of clay gravel, with 2 feet of cover. The railroad cut northwest of the station exposes from 2 to 6 feet of clay gravel or a distance of 2,000 feet, lying upon badly weathered crystalline schists and covered with from a few inches to 3 feet of clay and sandy soil. This gravel is not so good as that further south. On the Mayfield road, north of the railroad, at this point, a minimum of 2 feet of gravel is shown in a cut.

Anderson property.—On the Louis Anderson property along the plantation road between the Mayfield (Sparta) road at Norris Crossing and the Powelton road, road gravel outcrops at several places. The surface gravel here is probably about 3 or 4 feet thick. One mile north of the Sparta road, a well 22 feet deep shows clay for the first 10 feet, and then a coarse, clayey, granular quartz gravel for the rest of the depth. The surface showing on this property is not so good as that further south.

Baker property.—A well on the Hal Baker property, 4½ miles from Warrenton on the Warrenton-Powelton road 600 feet west of the intersection of this road and a north-south lane, shows 12 feet of coarse clay and sand gravel, having a one-foot sand cover, similar to that generally found in this region and extending from the surface and lying upon decomposed, variegated, pre-Cambrian schists at the bottom of the well. An 18-foot well, on the Powelton road 1,500 feet east of the last well and 10 feet higher, shows 10 feet of coarse, clay gravel, with pebbles from 1 to 3 inches, resting on crystalline schists. The gravel in the upper part of the well is composed of much smaller pebbles than that near the bottom. South of the road, a few hundred feet east of the last well and 10 feet higher, another well 18 feet deep exposes clay gravel for the entire depth. A third of a mile east of the last well, a road cut shows 8 feet of coarse gravel lying on the ancient crystalline schists. The sides and top of the hills south of the Powelton road at this point and for a mile west are capped with gravel ranging from a few feet to probably 10 feet in thickness.

Warrenton-Mitchell road.—Near the cross roads 5 miles from Warrenton, considerable surficial gravel was seen on the higher points. The gravel covers probably 30 acres on the Casian and adjoining properties. Gullies in the fields east of the Mitchell road show from 1 to 4 feet of quartz sand cover having quartz pebbles scattered through it. Below the sand 2 feet of good clay gravel occurs. The gravel does not appear to be more than 1 to 3 feet thick, according to evidence obtained from hand-dug wells on the Casian property. Beneath the gravel a mottled clay is found.

North of the cross roads, and in the direction of Warrenton, sandy clay gravel composed of rounded granular quartz pebbles occurs in most of the road cuts for a distance of 3,500 feet, except for about 1,000 feet where the land is low. Wells on either side of the road clearly show from 4 to 15 feet of gravel, the upper foot or two being generally sandy and the rest clayey. In all cases a mottled clay lies beneath.

Henry Tucker (colored) property.—The Henry Tucker property lies on the Mitchell-Warrenton road about 4½ miles from Warrenton. The gravel shows up well in the fields along the road and in some places is so thick as to prevent cultivation. A well west of the road, on this property, shows 5 feet of gravel, and on the opposite side another well shows at least 8 feet of similar gravel. There appears to be about 15 acres on this property having from 8 to 10 feet of gravel.

Dotson property.—The Dotson property, on the Mitchell road, adjoins the Henry Tucker place on the north. The well at the house shows 5 feet of clayey gravel.

Lynn Tucker (colored) property.—The Lynn Tucker property lies further east of the Dotson place, and a well on this property is said to penetrate 10 feet of gravel. A barren stretch, about 1,000 feet wide, lies north of the Dotson and Lynn Tucker places. The land here is much lower than to the north or south and well illustrates the tendency of the gravel to lie on or near the top of the hills or divides in this region.

Spence property.—The Spence property lies north of the Dotson place, and a well near the house shows 8 feet of clay gravel. Surface indications of gravel through here over a great many acres are very good, but no other certain information as to its thickness could be obtained.

Indications point to a large deposit of good gravel lying along the Mitchell road on the properties mentioned. The distance to the nearest station on the Georgia Railroad, Norris Crossing, is about 3½ miles, so that unless the demand for gravel becomes very great it will not pay to develop these deposits except for local road material.

Norwood.—Three miles north of Norwood, a 700-foot cut of the Georgia Railroad exposes from 4 to 10 feet of medium- to coarse-pebbled gravel, which is fairly well stratified and composed of subangular and rounded granular quartz pebbles. The matrix is a plastic, mottled clay. The deposit directly overlies the decomposed pre-Cambrian schists, and the overburden of clay ranges from a few inches to 4 feet.

A pit on the Atlanta public road, within a few yards of the railroad, has been opened in the gravel deposit for road material. The gravel in the pit is 7 feet thick, and the cover ranges from a few inches to 3 feet. Sample *T-56*, taken from the pit, shows a fineness modulus of 6.50 and 75 per cent retained on the 4-mesh screen. The deposit contains 10 per cent of clay and is well suited for road material, or, when washed, for concrete aggregate. A well, 800 feet further northwest on the public road, shows 6 feet of gravel with 5 feet of sandy clay cover. The area covered with gravel in this locality is about 8 acres, and a larger area is probably underlain with gravel at some depth. This deposit is not particularly well-suited for working on a large scale, due to thinness of the gravel and the fact that it rests on a very irregular crystalline rock surface which may cause the gravel to suddenly pinch out.

Rocky Comfort Creek.—An excellent coarse sand occurs in quantities suitable for local use in a branch of Rocky Comfort Creek, a half mile east of Warrenton, near the mill-pond.

WHITE COUNTY

The streams of White County have sand and gravel sufficient for local uses, but none is shipped.

Chattahoochee River.—Chattahoochee River, which forms the eastern boundary of the county, has plenty of coarse sand and gravel in bars along its course. Fair amounts occur near the bridge on the Helen-Clarkesville road, a sample of which was taken (*T-194*) and described under Habersham County, p. 303. Near Helen and Robertstown this river can supply both sand and gravel for local uses.

Considerable gravel occurs along most of Dukes Creek, particularly near the Helen-Cleveland road. Sand is also found along Little Tesnatee Creek in the southwest part of the county.

WILKES COUNTY

Granite and granite gneiss occupy most of the southwest part of Wilkes County and upon weathering has produced sand. No sand or gravel is mined in the county for shipment.

The sand used locally in Washington comes from a sandy belt produced by the weathering of underlying granite and which is crossed by the Ficklin road, 3 miles south of Washington. It is particularly prominent near and along small branches on the Sam Ray (colored) and Henry Potter (colored) places. This sand is medium-grained and somewhat loamy, but of fair quality for use in concrete. It is only from 1 to 3 feet thick and most of it, at the present pits, has been hauled away.

Sand similarly produced from the weathering of granite, and of the same quality as that south of Washington, occurs near Rayle, in the western part of the county, and also near the railroad depot at Tignall, in the north-central part of the county. The sand at Tignall is used for local building purposes.

Good sand occupies the bed of Fishing Creek, which flows eastward from the center of the county, and also occurs in Little River, a tributary of Savannah River, forming the southern boundary of the county. Bars in Little River are capable of supplying from 10 to 15 carloads, and they should be quickly replenished when exhausted, due to the swiftness and size of the stream. They would not, however warrant a large and steady production. A branch of the Georgia Railroad crosses the river near Ficklin and would provide transportation in case the demand warranted the installation of a centrifugal pump.

TESTS OF PIEDMONT PLATEAU SANDS

Number	Locality	Percentage coarser than each sieve													Effec. Size	Uniformity Coefficient	Fineness modulus	Specific gravity	Voids percentage	Weight per cu. ft.	Weight per cu. yd.	Color value of organic matter	Page number of text description	Number
		4	6	8	10	14	20	28	35	48	65	100	150	200										
1	Atlanta, Peachtree cr.	----	0.6	2.1	5.3	11.4	19.9	44.4	72.0	89.0	95.1	98.3	99.3	99.7	.281	2.19	2.45	2.67	43.4	94.1	2541	200	299	1
3	Bolton, Chattahoochee R.	----	----	----	----	----	----	0.1	1.0	14.2	61.5	89.6	97.1	99.4	.146	1.70	1.04	2.67	45.9	90.1	2433	20	301	3
4	Bolton, Chattahoochee R.	----	----	----	----	----	0.2	0.5	3.4	25.9	86.8	99.3	99.8	99.9	.192	2.80	1.26	2.69	44.8	93.7	2530	20	300	4
5	Conley, cr.	0.9	2.0	2.7	4.7	8.1	13.3	31.8	64.6	89.3	97.8	99.4	99.7	99.9	.288	1.89	2.32	2.67	45.9	90.3	2438	80	295	5
7	Dames Ferry, Ocmulgee R.	----	----	----	0.2	1.0	5.6	28.3	71.7	92.7	97.8	99.4	99.7	99.9	.311	1.75	2.21	2.66	42.6	95.5	2579	20	317	7
7a	Macon, Ocmulgee R.	0.7	1.5	3.8	10.4	21.2	40.0	62.5	87.5	95.3	98.6	99.4	99.7	99.9	.378	2.21	2.83	2.66	41.7	96.9	2616	125	------	7a
103	Thunder Spring	----	----	0.1	0.6	1.8	4.2	10.4	24.4	53.7	84.4	97.8	99.4	99.8	.183	1.92	1.64	n. d.	n. d.	n. d.	----	------	------	103
104	Yatesville	----	1.8	3.7	7.8	13.7	23.2	38.9	62.8	81.2	92.6	97.5	98.5	99.3	.228	2.55	2.35	2.64	43.1	93.7	2530	100	332	104
107	Griffin, cr.	12.1	19.0	27.0	37.8	48.5	60.8	73.1	85.2	94.6	97.9	99.6	99.8	99.9	.353	4.38	3.55	2.66	43.4	93.9	2535	100	327	107
108	Griffin, cr	1.4	3.4	5.5	10.5	17.3	28.8	43.6	61.5	76.3	88.2	96.5	98.5	99.3	.195	3.33	2.41	2.66	41.6	97.0	2619	100	327	108
109	Jackson, cr.	3.9	6.1	8.5	12.2	16.7	24.9	40.6	65.2	84.8	95.2	98.4	99.2	99.6	.251	2.33	2.62	2.66	40.8	98.6	2663	200	286	109
110	Eatonton, cr.	0.1	0.2	0.9	3.5	27.4	56.9	84.7	94.7	96.8	98.3	99.1	99.1	99.8	.498	2.08	2.62	2.63	46.9	90.6	2446	25	------	110
110a	Appling, bk.	----	0.1	0.5	2.5	6.5	14.8	29.5	51.6	69.1	81.6	90.6	94.5	99.7	.151	3.36	1.96	2.66	45.2	91.0	2557	300	293	110a
111	Appling, cr.	0.4	2.9	8.2	19.5	35.0	55.6	79.5	94.0	98.4	99.2	99.6	99.8	99.9	.464	2.34	3.21	2.60	43.0	92.6	2550	200	293	111
112	Watkinsville, cr	2.8	4.5	8.0	18.3	36.1	60.0	80.3	93.2	96.7	98.6	99.5	99.7	99.9	.459	2.43	3.23	2.66	43.8	94.2	2543	100	322	112
113	Madison, cr.	----	0.5	1.9	11.9	28.6	55.1	86.0	94.7	98.3	99.5	99.5	99.7	99.7	.511	2.19	3.09	2.66	42.3	96.1	2595	150	319	113
114	Lexington, cr.	8.2	11.9	15.5	20.4	25.9	35.1	48.7	68.3	86.9	90.6	96.3	98.1	99.3	.222	3.31	2.76	2.64	40.3	98.2	2651	100	323	114
115	Athens, cr.	0.9	3.3	6.5	13.4	23.1	35.4	54.1	74.2	84.6	92.6	96.3	98.0	99.2	.236	3.27	2.66	2.64	47.5	86.6	2338	50	290	115
116	Monroe, cr.	0.1	0.4	1.3	4.5	10.0	19.6	36.0	52.2	72.3	83.2	94.0	96.7	99.2	.170	3.22	2.14	2.67	42.3	96.2	2597	150	333	116
118	Porterdale, bk.	----	----	0.1	0.4	1.2	7.3	12.1	30.3	55.1	81.2	93.0	96.2	99.1	.163	2.26	1.61	----	----	----	----	150	322	118
119	Henry County, South R.	0.2	0.8	2.0	5.6	12.3	23.8	43.0	62.8	85.2	95.2	98.8	99.5	99.9	.253	2.48	2.42	2.66	42.8	95.0	2565	300	309	119

NOTE: R=river, cr=creek, bk=bank.

TESTS OF PIEDMONT PLATEAU SANDS

Number	Locality	Percentage coarser than each sieve													Effec. Size	Uniformity Coefficient	Fineness modulus	Specific gravity	Voids percentage	Weight per cu. ft.	Weight per cu. yd.	Color value of organic matter	Page number of text description	Number
		4	6	8	10	14	20	28	35	48	65	100	150	200										
121a	Almon, bk.	----	----	----	0.1	0.2	0.4	1.3	9.2	44.1	79.9	95.4	98.5	99.6	.168	1.84	1.41	2.66	46.1	89.6	2419	300	322	121a
123	Hogansville, cr.	0.3	0.6	1.3	5.8	12.6	29.4	54.5	81.6	94.3	98.5	99.7	99.8	99.9	.334	2.16	2.63	2.67	44.9	93.2	2516	50	315	123
124	LaGrange, cr.	1.4	2.6	4.6	8.5	14.6	25.9	44.8	71.6	89.3	96.5	99.0	99.6	99.8	.287	2.27	2.54	2.66	43.1	95.5	2568	150	330	124
125	LaGrange, bk.	0.5	7.0	13.6	24.6	35.9	52.4	72.8	90.8	97.6	99.0	99.5	99.0	99.8	.424	2.50	3.20	2.66	39.0	96.4	2549	60	330	125
126	Carrollton, cr.	9.8	19.0	26.2	34.3	41.5	50.3	62.5	79.5	89.9	95.8	98.3	99.0	99.6	.296	4.32	3.28	2.67	39.2	101.3	2735	trace	288	126
128	Hogansville, bk.	1.7	3.9	6.5	13.3	23.7	41.5	63.6	85.6	94.8	98.6	99.5	99.7	99.9	.359	2.40	2.90	2.66	41.6	95.6	2581	800	330	128
129	Carrollton, cr.	5.4	6.1	6.8	7.7	9.2	12.5	20.9	43.4	70.2	88.1	96.6	98.7	99.6	.194	2.28	2.09	2.66	43.2	94.5	2552	150	288	129
130	Chapel Hill, cr.	0.1	1.5	4.7	13.1	24.4	46.4	70.5	86.4	92.9	96.2	98.5	99.3	99.8	.351	2.62	2.91	2.66	38.8	102.0	2754	600	296	130
189	Clayton, cr.	8.4	9.0	14.8	21.5	25.5	29.1	40.3	59.1	75.6	87.7	95.5	98.0	99.3	.190	3.13	2.59	2.66	42.0	96.4	2549	400	326	189
192	Clarkesville, cr.	2.8	4.6	8.0	14.5	21.7	32.5	47.6	67.8	83.7	93.3	97.5	98.8	99.6	.238	2.99	2.61	2.67	40.4	99.4	2684	200	303	192
193	Toccoa, Broad R.	0.4	0.6	0.9	2.2	4.7	11.9	28.2	47.0	67.2	80.7	92.1	96.8	98.9	.158	3.05	1.93	2.66	43.1	94.6	2555	100	328	193
195	Auraria, bk.	3.8	4.4	6.2	12.4	21.9	39.4	62.9	85.9	94.9	97.8	99.2	99.5	99.8	.361	1.65	2.89	2.67	46.5	89.5	2416	150	312	195
196	Dixon, cr.	5.5	7.2	9.8	16.0	22.8	31.1	44.5	61.3	76.9	89.3	95.5	97.7	99.2	.201	3.33	2.55	2.64	41.4	96.7	2558	350	-----	196
197	Gainesville, Chestatee R.	10.8	15.6	21.6	31.8	44.0	60.4	76.4	88.2	94.2	96.9	98.8	99.4	99.8	.380	3.49	3.46	2.69	41.9	97.5	2632	250	304	197
198	Gainesville, bk.	0.2	0.6	1.4	3.8	6.8	13.4	25.8	49.5	70.3	85.1	94.2	97.3	99.0	.175	2.78	1.99	2.67	41.4	97.5	2632	700	304	198
199	Suwannee, cr.	9.0	14.5	22.2	35.7	47.1	60.1	72.0	82.3	90.4	94.9	97.5	98.6	99.5	.301	4.82	3.30	2.66	39.9	100.0	2700	100	303	199
201	Winder, cr.	2.1	3.8	6.4	12.5	22.4	37.4	55.2	72.3	85.4	94.2	99.0	99.6	99.8	.249	3.13	2.71	2.59	37.4	101.4	2738	trace	310	201
203	Jefferson, cr.	2.7	4.6	6.9	11.2	19.2	34.2	54.0	72.8	84.3	92.3	96.1	98.2	99.5	.233	3.27	2.63	2.62	42.6	94.1	2541	100	310	203
203a	Elberton, cr.	0.3	0.7	2.0	5.2	11.7	22.7	40.9	65.0	84.6	94.8	98.8	99.5	99.8	.249	2.42	2.38	2.68	42.0	96.5	2552	150	296	203a
204	Hartwell, cr.	2.9	6.2	10.0	15.9	23.3	32.1	44.2	67.1	84.1	93.1	98.0	98.9	99.5	.244	2.75	2.62	2.62	43.2	92.3	2492	200	308	204
205a	Comer, cr.	0.9	1.4	2.9	6.2	13.1	24.1	45.3	74.3	90.4	96.9	99.2	99.7	99.9	.298	2.18	2.52	2.67	40.6	96.1	2540	200	-----	205a
261	Greensboro, cr.	5.1	14.9	29.6	52.2	70.8	85.8	94.7	98.4	99.2	99.7	100.0	-----	-----	.718	2.83	4.05	2.62	38.8	100.0	2700	100	302	261

TESTS OF PIEDMONT PLATEAU GRAVELS

Number	Locality	Percentage coarser than each sieve																Fineness modulus	Page number of text description	Number
		1¼	¾	½	4	6	8	10	14	20	28	35	48	65	100	150	200			
180	Acworth, cr.	13.6	21.6	26.9	54.5	55.7	56.7	58.3	60.2	63.8	70.7	83.4	93.0	97.6	99.1	99.5	99.8	4.96	292	180
187	Hiwassee, cr.	6.1	16.6	25.4	46.0	51.2	55.2	59.6	62.7	66.2	70.4	76.5	85.6	92.7	96.9	98.3	99.3	4.55	331	187
188	Hiwassee, cr.	10.9	23.6	35.9	57.7	63.4	66.0	68.5	70.4	72.5	74.7	78.1	82.8	88.8	94.3	96.5	98.2	5.16	328	188
194	Cleveland, Chattahoochee R.	1.7	8.5	18.4	37.2	48.6	45.6	53.1	61.5	72.5	83.4	92.8	97.0	98.3	99.2	99.6	99.8	4.42	303	194
200	Duluth, cr.	2.4	7.7	16.9	47.7	56.8	64.2	71.1	76.3	81.1	86.2	91.1	94.3	96.2	97.5	98.1	99.0	4.93	302	200

THE PALEOZOIC AREA[1]

EXTENT AND SIZE

Within the Paleozoic area of Georgia is included the extreme northwest corner of the state comprising all or parts of Dade, Walker, Catoosa, Chattooga, Floyd, Polk, Murray, Gordon, Bartow and Carroll counties.

PHYSIOGRAPHY

In contrast with the Appalachian Mountains on the east and the Piedmont Plateau on the south, the Paleozoic area presents, for the most part, long, narrow, regular ridges, with broad, rolling valleys between.

That part of the area in Dade and the western part of Walker and Chattooga counties is a high, level plateau known as the Cumberland Plateau having an average elevation of 1,800 feet. Between this plateau and the Appalachian Mountains the regular succession of ridges and valleys comprise the Appalachian Valley Province which is part of a similar zone extending southward from Pennsylvania. Its average elevation is 850 feet. Most of the streams traversing the area are not very swift and have sandy or muddy bottoms.

GEOLOGY

The Paleozoic area is underlain by deposits of sandstone, shale, slate, and limestone of Cambrian, Ordovician, Silurian, Devonian, and Carboniferous ages. Since deposits of sandstone suitable for glass making occur in the sandstone formations, and deposits of chert gravel as residual products in some of the limestone formations, the various formations will be considered.

CAMBRIAN SYSTEM

The Cambrian System is divided into Altered and Unaltered Cambrian. The Altered Cambrian, long considered Pre-Cambrian, occupies a belt from eight to twenty-five miles wide, lying between the Archean rocks and the unaltered Paleozoic rocks. It consists of almost 10,000 feet of slates, schists, quartzites, conglomerates, and mar-

1 Abstracted from the following sources:
McCallie, S. W., Notes on the geology of Georgia: Jour. Geology, Vol. 27, pp. 168-175, 1919.
Maynard, T. P., Limestones and cement materials of north Georgia: Georgia Geol. Survey. Bull, 27, pp. 82-108, 1912.

bles, all of which are highly metamorphosed, but usually retain some evidence of sedimentary origin. Some of the quartzites may be pure enough for glass purposes. The Unaltered Cambrian occupies irregular strips throughout the Paleozoic area.

The Weisner quartzite forms hard ridges and consists of heavy beds of fine to coarse quartzite ranging into conglomerate. In places this material attains considerable purity.

The shales belong to the Cartersville, Apison, and Rome formations and are generally calcareous with local sandy lenses. The limestones which make up part of the Shady, Conasauga, and Knox dolomite formations may be intercalated between shales and are usually blue and quite siliceous, leaving beds of cherty gravel upon weathering.

ORDOVICIAN SYSTEM

The *Chickamauga limestone* is the only entirely representative member of the Ordovician system in Georgia. It is a succession of blue limestones and calcareous shales. It is 200 feet thick and largely forms the valleys in the area. From its decay large deposits of chert gravel have been formed.

In the eastern part of the area the Rockmart slate is included in the Ordovician, making the total thickness of this system 2,500 feet.

SILURIAN SYSTEM

The *Rockwood formation* consists of sandstones and shales and varies from 600 to 1,000 feet in thickness. The sandstones are usually thickly bedded, forming ridges, as at Rocky Face and Chattoogata Mountain, in Whitfield County, and may be of sufficient purity to be suitable for the manufacture of glass. Intercalated red, brown, and blue shale and shaly sandstone is common in the formation.

DEVONIAN SYSTEM

The representatives of the Devonian formation are few, and occur mostly in the vicinity of Rome. They consist principally of a black shale and some sandstone with interbedded shale.

CARBONIFEROUS SYSTEM

The Carboniferous rocks are found at their greatest thickness on the Cumberland Plateau. They have been divided into the Upper Carboniferous, or Pennsylvanian, and the Lower Carboniferous, or Mississippian.

PENNSYLVANIAN GROUP

The *Lookout formation* lies unconformably on the Bangor formation and consists of sandstone, conglomerates, shales, and some coal. Heavy, somewhat impure, sandstone and conglomerate beds make up the lower and upper parts of the formation, and shale and sandstone is interbedded between. None of the material is believed fit for commercial glass making.

The *Walden sandstone* is the youngest Paleozoic formation in Georgia and is composed of sandstones, conglomerates, shales, and several coal beds. It is similar to the Lookout formation, and, like it, does not contain extensive beds suitable for glass making.

MISSISSIPPIAN GROUP

Fort Payne chert is a limestone containing a large amount of chert. Upon weathering the chert remains as residual deposits somewhat resembling that of the Knox dolomite, which is used for road material in many places.

The *Floyd shale* consists of vari-colored, calcareous shales, sometimes sandy, and merging into thin beds of limestone. Heavy bedded, blue limestones also occur through the formation.

The *Oxmoor sandstone* lies upon the Floyd shale and consists of coarse white to brown sandstone and conglomterates. No extensive beds suitable for glass making occur in the formation.

The *Bangor formation* consists of heavy bedded, blue limestone some beds of chert in its lower part, and shales of variable thickness in the upper part. No sandstone is found in it.

DETAILED DESCRIPTION OF INDIVIDUAL COUNTIES

BARTOW COUNTY

Sand is shipped from Emerson, and small deposits of stream sand and bank gravel occur throughout Bartow County. About 1900 roofing gravel was shipped from the vicinity of Kingston.

Emerson.—Fine- and coarse-grained sand has been deposited by Pumpkinvine Creek, 1½ miles south-southwest of Emerson, along both sides of the stream, near the trestle of the branch railroad that ran from Emerson to the brown iron mines, on the property of C. A.

Puckett, of Emerson, and J. L. McElroy, of Norcross. The stream is about 40 feet wide at this place. Close to it, on the west side, a fine-grained plaster or brick sand attains a thickness of from 2 to 5 feet. It is dark brown and has mica and some organic matter scattered through it. The deposit, which covers about 10 acres, is worked by C. A. Puckett and the sand hauled a half mile by wagon to the railroad spur where it is loaded on cars and shipped to nearby towns. The surface of about one acre of the deposit is covered to a depth of 2 feet with a fine-grained, sharp, clean, white sand that has been shipped to Philadelphia and points in Ohio for use in sanding clay products before burning. It is said to be well suited for this purpose. Sample *T-176,* typical of this fine-grained sand, has a fineness modulus of 0.94, and only 8 per cent is coarser than 48 mesh. The supply of this type of sand is very limited.

On the same side of the creek and further north, a pit which covers about an acre has been opened.

Section at sand pit, 1½ miles southwest of Emerson

	Feet	Inches
Gray, fine- to medium-grained sand with a few stringers of pebbles from ⅛ to ¼ inch running through it	5–6	
Reddish-brown clay		6
Yellow, medium-grained sand	2	

The upper sand has been shipped largely to adjoining towns and is suitable for brick and plaster work. On the same side of the creek and closer to it near the pit, is apparently from 4 to 6 feet of a rather coarse-grained sand which is suitable for concrete. No opening has been made in this part of the deposit. Sample *T-177* shows it to have a fineness modulus of 2.40 and 88 per cent coarser than 48 mesh. The organic matter color value is 150. The sand is gray, and the grains are mostly of quartz and chert. The coarse sand probably occupies less than an acre and is surrounded by the finer-grained material.

Sand extends along Pumpkinvine Creek for about a mile, reaching 400 feet back on the east side, and to a lesser extent, and of somewhat inferior grade, on the west side.

Etowah River.—At the Wooden Bridge northwest of Etowah River, a few feet above the river level, and 50 feet back from it, a fine- to medium-grained sand has been deposited. The sand is hauled to Cartersville, 2 miles distant, and used principally in brick and plaster work for which it is better suited than for concrete. The deposit extends for a half mile down the river, with some interruptions and is from 3 to 6 feet thick. Sample *T-179,* obtained from a small pit just below the Wooden Bridge, has a fineness modulus of 1.89 and 78 per cent is coarser than 48 mesh. The organic color value is 100. The sand is dark gray and fairly clean, although it contains some mica, barytes, and coal particles.

Should the demand warrant, it is likely that a centrifugal pump or bucket dredge would obtain plenty of coarse sand and even gravel on submerged bars or near the mouths of tributary creeks.

Allatoona Creek, which has been dredged for part of its course in Bartow County, has bars of good, coarse-grained sand and gravel. In the southeast part of the county where the Western & Atlantic Railroad crosses the creek, sand was formerly obtained for locomotive purposes and hauled to Atlanta where it was dried.

GRAVEL

Thin deposits of clay gravel composed of tough quartz pebbles occur on the sides and top of the second terrace which overlooks Etowah River and also in the second bottom of this river. A small deposit occurs on the Dixie Highway, 1¾ miles south of Cartersville where it is shown tilting at an angle of 45° in a road cut beneath a small cemetery The cut shows 8 to 10 feet of gravel which underlies 2 or 3 acres of the hill above. Coarse-pebbled gravel also occurs in the fields along the second bottom of Etowah River near this point at a number of places, but their thickness is not likely to exceed a foot or two.

Gravel also occurs on the slopes of the terrace above Pumpkinvine Creek. It is exposed on plantation roads on the Puckett and adjoining properties.

A gravel pit was formerly worked on the Mrs. L. A. Jones property, lot 624, in the Etowah River bottoms, and a few hundred yards south of the Dixie Highway, and east of the wagon road leading to the barytes grinding mill. The gravel usually occupies slight rises of a few feet and appears to irregularly underlie several acres in this vicinity.

Adairsville.—One mile south of Adairsville on the Dixie Highway, a branch of Oothkalooga Creek has small quantities of rather soft-grained sand, shale and limestone gravel of poor quality. Sample *T-175*, from this deposit, has a fineness modulus of 5.53 and 51 per cent coarser than 4 mesh.

Kingston.—According to Mr. J. D. Rollins, of Kingston, over 500 carloads of roofing gravel were shipped from small pits near Kingston about 1900. Most of the gravel was worked out at that time but it is possible that other deposits may be found in the vicinity.

Molding sand.—Near the branch railroad running southwest from Emerson, a deposit of very fine-grained, silty, molding sand has been mined about three-quarters of a mile from Emerson on the public road. It occurs on the slope of the hill in small deposits containing a few cubic yards each and has apparently been derived from the weathering of the Weisner quartzite. Small amounts are used by foundries in Cartersville.

CATOOSA COUNTY

The only sandstone of consequence in Catoosa County is found in the Rockwood formation, although fairly pure sandstone layers may be encountered in the Knox dolomite. Most of the streams have good concrete aggregate, and their bottoms in many cases have differing amounts of molding sand. Small quantities of molding sand are produced in the county, but no building sand is shipped.

Ringgold.—South Chickamauga Creek, from Graysville to Ringgold, has some clean, chert gravel, but south of Ringgold very little is found in it, although sand was shipped from along its banks, two miles below Ringgold, some years ago.

Brockman property.—On the Edward Brockman place, 1½ miles west of Ringgold, west of South Chickamauga Creek, is a deposit of fine-grained sand suitable for brick mortar, but much too fine for plaster or concrete. The sand has been opened to a depth of 5 feet in places and hauled to Ringgold. It is composed of quartz and chert grains, gray and loamy with a few pebbles in it. Sample *T-163* shows it to have a fineness modulus of 1.04 and 31 per cent coarser than 48 mesh. The sand has only a trace of organic matter.

Clark property.—South of the Brockman property, J. H. Clark has a similar deposit of brick sand and molding sand, along South Chickamauga Creek. He ships both grades of sand to Chattanooga, Knoxville, and Birmingham.

Similar sand, less desirably located with regard to transportation, occurs along this creek on a number of other properties in the vicinity of Ringgold.

Hurricane Creek has small amounts of gravel, especially near its junction with South Chickamauga Creek, east of Graysville. At a number of points along West Chicamauga Creek in the western part of the county, angular chert gravel and sand, in quantities sufficient for local purposes, occur.

Molding sand.—The bottoms of the larger creeks in Catoosa County have large quantities of good molding sand, deposited by this stream during flood periods Deposits of this kind are almost universally associated with the streams of northwest Georgia, but the proximity of this particular locality to Chattanooga, with its many foundries, has led to its development both in Catoosa and Whitfield counties.

Brockman property.—An excellent deposit of molding sand occurs on the Brockman place, west of South Chickamauga Creek, 1½ miles west of Ringgold. The sand is found in the first bottom of the stream, almost from the bank to a point about 600 feet back. Pits opened along the creek show it to have a maximum thickness of 10 feet. The upper 18 inches of the deposit is a gray, gritty soil which is usually ploughed in with the rest of the material when loosened. The next 3 feet is a silty, red, medium-grained, smooth sand which is said to be the best of the deposit. Beneath this the sand becomes finer and darker for the rest of the section, and it may contain a few chert fragments.

The sand is hauled to the railroad at Ringgold where it is loaded on cars and shipped to Nashville, Chattanooga, and Birmingham.

Sand similar to that on the Brockman property is shipped from the J. H. Clark place to the south and also occurs on other places bordering the creek.

On the Dixie Highway, 2 miles south of Ringgold, 10 feet of what appears to be a good red and yellow molding sand occurs, underlain by hard chert gravel, 5 feet thick. This is simply a local pocket containing about 600 cubic yards.

CHATTOOGA COUNTY

Although no sand or gravel has been produced commercially, adequate deposits for local use occur in most parts of Chattooga County.

Sandstone, usually impure, is found in the Rockwood, Lookout, and Walden formations. Chert, derived from the weathering of the Knox dolomite and the Fort Payne formation, has been mined commercially near Summerville for road purposes.

Dill property.—A half mile west of Tidings' store on Whitehead Creek and close to the Rome & Northern Railroad, a small deposit of coarse, concrete sand occurs which was formerly shipped in small quantities.

Good sand is also found in West Armuchee Creek, near the crossing of the Rome road. The sand is coarse-grained and of good quality and is used in local construction.

Pollock property.—On the Chattooga road, 1¼ miles east of Lyerly, on the N. L. Pollock property, is a flood-plain deposit of 3 or 4 acres of very fine-grained sand, suitable for brick or plaster work. The sand is 2 or 3 feet thick and is underlain by a silty material probably suitable for foundry purposes. The sand is hauled to Lyerly and Berryton and used in building. Sample *T-149* shows a fineness modulus of 95 and 15 per cent coarser than 48 mesh. The color value of the organic matter is 200. Sand of this type occurs close to the river in smaller quantities at other places in the county, for example, east of Berryton, and near Chattoogaville.

On most of the branches at almost any point in the county, a few cubic yards of clean chert gravel can be found for local work. Larger deposits occur in bars at a few places along Chattooga River, but as a rule good concrete sand or gravel in any but small quantities is hard to find. Small amounts of good sand and gravel are found in the streams, branches, and sloughs around Summerville, and this material serves for most local construction purposes. Good concrete material in small quantities also occurs in the small creek just east of Gore.

CHERT

Bittings property.—A large chert pit on the N. K. Bittings property, on the Central of Georgia Railway, 1 mile south of Summerville, has been operated for 30 years, and up until the spring of 1919 the chert was shipped to various points in Georgia and Tennessee for road building. (Plate XIX-A.) When visited in August, 1919, the spur had been taken up, and the chert was used only for local road building. The face is 50 feet high in places, and the pit covers 2 or 3 acres. The chert is greatly broken up and readily crumbles to angular fragments 1 to 5 inches in size when broken down with picks or by small shots of dynamite. Decayed limestone and chert serves as a binder, so that the material is fairly well-suited for roads, although roads built from it are usually very dusty. It is not good for concrete construction unless washed.

Analysis of chert from Bittings pit, one mile south of Summerville, T-148

Ferric oxide (Fe_2O_3)	0.63
Silica (SiO_2)	97.16

Smaller chert pits have been opened at several places in the county and the material used locally in road building. Residual chert, produced from the weathering of the Knox dolomite, is very extensively scattered through the county. A belt, 1 mile wide, favorable for the occurrence of this material, extends from near the Alabama line, 1 mile west of Chattoogaville, to the county line north of Trion. This belt is close to the railroad 3 or 4 miles south of Summerville and for several miles north of Trion. Similar areas occur near Menlo, in Broomtown Valley, and near Talliaferro, and also along the Central of Georgia Railway from Trion to the county line.

Ramsey property.—On the W. W. Ramsey place, on the left bank of Armuchee Creek, where the Rome-Summerville road crosses it, and just south of Armuchee village, a flood-plain deposit of fine-grained sand occurs. The deposit covers about 5 acres, and the sand is from 4 to 8 feet deep pale yellow, and has considerable loam. It is suitable for brick and plaster work and is used locally for construction. Sand from this property is hauled to the railroad a quarter mile distant and shipped to nearby points. Similar sand occurs west of the public road, 6 feet thick, but it is not known whether this thickness is extensive.

Molding sand.—A deposit of what appears to be fairly good molding sand occurs along the southern bank of Chattooga River at the Trion steel bridge. The material is 10 feet thick and is uniform throughout except that it is more clayey at the base.

Sand more favorably suited with respect to transportation might be found near the railroad bridge over the river a short distance west of this point.

DADE COUNTY

Sandstone is particularly prominent in the Walden and Lookout formations in Dade County, but its value is small. No sand or gravel has been commercially produced in the county, and good deposits of even small extent are rare.

Trenton.—One mile east of the town, where the steel bridge crosses Lookout Creek, is a deposit of fine-grained, somewhat loamy sand used locally for building purposes. It occurs in the creek bottom on both sides of the creek and is not more than 2 or 3 feet thick.

Rising Fawn.—Two miles north of Rising Fawn on Lookout Creek, is a deposit of 5 or 6 acres of fine-grained sand from 2 to 3 feet thick and underlain by a clayey sand apparently suitable for some foundry purposes. Sample *T-158*, representing this deposit, has a fineness modulus of 1.40 and 38 per cent is coarser than 48 mesh. The organic matter color value is 250. The sand is a dark grayish-brown, and the grains are mostly of chert and quartz.

Coarse-grained sand and gravel in small quantities, suitable for concrete work, are found on Crawfish Creek, near the crossing of the Rising Fawn-Trenton road.

Sandstone.—The lower parts of Lookout and Sand mountains in this county are composed of limestone, but from the 1,500-foot level upward, sandstone, belonging to the Lookout and Walden formations, occurs. This sandstone is mostly yellowish- to reddish-brown and has intercalated shale and coal layers, and only rarely is it white enough to suggest its use in the manufacture of glass.

FLOYD COUNTY

The Lookout and Rockwood formations in Floyd County contain considerable sandstone available for silica materials, but hardly pure enough for glass. Sand and gravel are dredged from Oostanaula and Etowah rivers at Rome, and large quantities are used both in Rome and other parts of the state. Gravel pits have been opened at several points in the county for road material.

Rome Sand and Gravel Company.—The Rome Sand and Gravel Company, managed by E. L. Norrels of Rome, dredges sand from Oostanaula River at the company's wharf at the foot of Second Avenue. Sand is also obtained from Nixon's Island, 1½ miles below the wharf where it is loaded by hand on a lighter and towed to the city by a small motor boat. Both sand and gravel is obtained at Batty's shoals, 1 mile above Rome near the pumping station. Most of the gravel in the river bed at Rome has been removed, and what is left is said to have a crust, 6 or 8 inches thick, so hard as to be broken by the grab-bucket only with difficulty. What gravel is recovered is made up of 50 per cent of pebbles from ½ to 2 inches in size, and the remainder is sand.

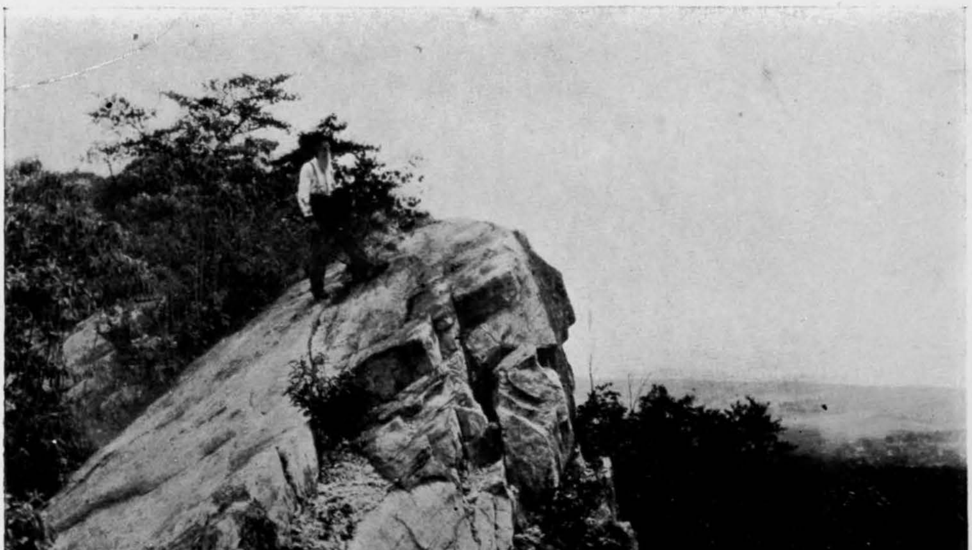
Sand was formerly pumped from the river by means of a 6-inch centrifugal pump, but the loss of the pump, when the barge to which it was attached was sunk, has not yet been replaced. At present the sand is scooped from the sand barges and loaded in cars or put in a stock pile with a 30-horsepower whirler or stiff-leg boom having a one-cubic-yard scoop-bucket. When gravel was recovered from the river, the material was first passed through 1½-, 1-, and ¼-inch revolving trommels, so that two grades of gravel and one grade of sand were obtained.

A ladder elevating device, consisting of 27 buckets, made of bridge steel, has been used in raising sand and gravel from the river bed. When in use, it was attached to the side of the barge, but it caused the barge to list so much that it was impossible to get a full load of material. It is intended to prevent this difficulty by cutting a hole in the center of the barge and installing the elevator over it.

Sample *T-134* was obtained from the shores of Nixon's Island and is used as brick sand. It has a fineness modulus of 1.25 and 38 per cent is retained on the 48-mesh sieve. The organic matter color value is 2,000. This sand is shipped to Cedartown, Cartersville, Atlanta, and other North Georgia points.

N. G. Watson Sand Company.—Mr. N. G. Watson obtains his sand from Etowah River, on the east side of Rome. This river is swifter than Oostanaula River and it is natural that the material in its bed should be somewhat coarser. Three grades of material are produced: gravel, which is dredged from the river where the water is shallower and has caused the deposition of coarse sand and pebbles; concrete sand, composing two-thirds of the gravel, is screened from the natural sand and gravel mixture obtained from the stream bed; and brick sand, obtained from the banks of a small island, a short distance below the dock.

A. GRAVEL DEPOSIT NEAR ROME-LIVINGSTON ROAD, 7 MILES WEST OF ROME, FLOYD COUNTY



B. WHITE SANDSTONE DEPOSIT, ROCKWOOD FORMATION, ROCKY FACE, WHITFIELD COUNTY

The gravel is scooped from the river by a man with a long pole on the end of which a scoop is fastened. The pole is supported by a post on the barge. The barge holds about 7 cubic yards. The brick sand, from the shores of the island, is shoveled by hand into the barge which is then poled to the landing. This sand is probably 10 feet thick. The sand and gravel is used locally in Rome and is of exceptionally good quality. Sample *T-136* is typical of the brick sand from the island and shows a fineness modulus of 1.38 and 40 per cent retained on the 48-mesh sieve. The organic color value is 560. The sand is dark gray, and the grains are of quartz, chert, and mica.

Sample *T-137* represents the river gravel from the submerged island and has a fineness modulus of 5.49 and 54 per cent is coarser than 4 mesh. The pebbles are tough and of white sandstone and quartz, with some flint, red sandstone, dolomite, and limonite.

The medium-grained sand obtained from this island (*T-138*) shows a fineness modulus of 1.82 and 76 per cent coarser than the 48-mesh screen. The organic color value is 400. The sand is light brown and composed mostly of quartz and chert and some mica and limonite.

GRAVEL

Large amounts of clay gravel are found in the county on the upper terraces overlooking Coosa River and to a less degree on the terrace of Etowah River at Rome. Most of the gravel is rather remotely situated with respect to transportation, but it is desirable and available for road construction purposes in the county.

Rome.—On the hills overlooking Etowah River from the north in the northeast part of Rome, gravel occurs from 3 to 10 feet thick. On the hill occupied by the large schoolhouse above the Southern Railway bridge over the river, gullies show the following section on the northwest side of the hill:

Section at Schoolhouse Hill, Rome

	Feet
Sandy, clay gravel, pebbles ½ to 2 inches composing 60 per cent of the mass	5
Yellow clay	10
Clay gravel, pebbles ½ to 3 inches, composing 70 per cent of the mass	10
Clay	4
Clayey gravel, not so coarse-pebbled as upper layers	5
Clay	5
Fairly good clay gravel	8–10

This section shows a large amount of gravel, but the lenses thin out and pinch out quickly so that the deposit can not be judged from one section. Although the area of the hill is 10 acres, probably not more than 3 acres contain merchantable gravel. Sample *T-139* has a fineness modulus of 6.63 and 87 per cent coarser than 4 mesh. The pebbles are mostly of tough, sub-angular quartz, a few of which are decayed.

On the south side of the hill, the lower 35 feet are composed of clay, but near the top a southward pitching seam of coarse-pebbled gravel, 6 feet thick, is found, indicating that the gravel exposed on the opposite side does not occur here. The railroad cut, northeast of the schoolhouse, shows limestone for the lower three-fourths of the hill, with clay and gravel 10 feet thick, above.

Two miles east of Rome, the hills adjoining the clay pits of the Rome Brick Company show considerable gravel. Road cuts east of the pit disclose 15 feet of irregular gravel, but it is not exposed in the pit which is only 500 feet west.

Gravel outcrops are common along the Kingston road to a distance of 3 miles from Rome. Thicknesses up to 6 and 8 feet were seen, but it usually appeared to be very irregular and likely to thin or pinch out quickly, and the clay content was generally high.

Dean property.—A small pit has been opened near the Black Bluff (Foster's Mill) road, on the H. A. Dean property, 1 mile from the center of Rome and near the city limits. (Plate XIX-B.) The gravel is used in road construction in the county. The face of the pit is 150 feet long and shows a maximum of 8 feet in the cut and probably a foot more below. The gravel is roughly stratified and is overlain at this point by from 2 to 4 feet of clay with a few pebbles in it. The matrix of the gravel is a sandy clay with a high cementing value so that the material is well suited for gravel roads. The hill appears to contain about 2 acres of gravel, but the cover will increase considerably as the hill is worked into. Sample *T-143* showed a fineness modulus of 6.36 and 74 per cent coarser than 4 mesh. The pebbles are mostly of tough quartz, although a few rotton ones are found. Similar deposits should be found along the river at about the same elevation due to former deposition when it flowed at a higher level.

South Rome.—Sewer operations along Second Avenue and north of this street, east of Etowah River, disclosed 10 feet of clay gravel overlain by a thin gravelly clay. The gravel is composed of 1- to 2-

inch pebbles making up 60 per cent of the mass. Most of this material is rather limited in extent and occurs in a built-up section of the city, hence it is not likely to be available.

OTHER DEPOSITS

Dikes Creek.—Where the Kingston road crosses Dikes Creek, 5 miles from Rome, an excellent, clean, rounded gravel with pebbles from ½ to 2 inches in diameter and composed mostly of granular quartz occupies the stream bed. The bed is 30 feet wide, and the gravel covers most of it to a depth of 1 to 3 feet. Sample *T-146,* taken from this deposit, has a fineness modulus of 7.20 and 85 per cent coarser than the 4-mesh sieve. This is an excellent concrete gravel and is trucked to Rome and sold through the Rome Sand and Supply Company.

Bright property.—A pit has been opened in gravel occurring at the top of a hill on the T. J. Bright place a quarter of a mile south of the Southern Railway and 8¾ miles west of Rome on the Alabama road. The gravel has been used by the county in road construction but has been found to have too large a clay percentage to make good roads. About a quarter acre has been removed, and the face of the pit is 15 feet high, showing the following section:

Section at Bright pit, 8¾ miles west of Rome

	Feet
Red, clayey soil	2
Coarse-pebbled, red clayey gravel, with a number of rotten pebbles decayed to sandy clay	9
Clayey gravel with smaller pebbles, a large percentage of which have decayed	5

Sample *T-142* from this pit shows a fineness modulus of 6.06 and 66 per cent retained on the 4-mesh sieve.

The deposit is roughly stratified and shows several lenses of coarse sand especially in the lower part of the section. The northern part of the hill is likely to have a thicker cover over the gravel, possibly reaching 10 feet, but on the other sides there should be little or no overburden. Apparently 6 or 8 acres are underlain with easily accessible gravel. Although gravel appears to the bottom of the hill, it is probably float, and the upper 20 feet only can be depended upon. The hills adjoining to the south and to the east also contain some gravel.

Rome-Livingston road.—The Livingston road parallels the south side of Coosa River at the upper terrace level and is favorably situated for the exposure of old river gravels. The most prominent exposure is at Bush Arbor Church, 7½ miles from the river, where 10 feet are shown in the road cut for a distance of 300 feet. The gravel is clayey and coarser-pebbled at the base, becoming finer and thinner toward the top. Sample *T-132* showed a fineness modulus of 6.47 and 77 per cent retained on the 4-mesh sieve. The pebbles are tough, rounded, and sub-angular flint and quartz. No stratification is apparent. The binder is good and the material well suited for road building. In the fields to the south of the road for half a mile from the road, excellent clay gravel, somewhat sandy near the top, is exposed. (Plate XX-A.) The maximum thickness noted was 20 feet of solid gravel with 10 feet of poorer material above this, but still suitable for many purposes. The nearest railroad point is Agate on the Southern Railway, 3 miles southeast.

Webb Creek.—Just above the Livingston road crossing, Webb Creek has several hundred cubic yards of excellent, clean, concrete gravel. Further west, and near this same road, smaller deposits of bank gravel occur on the Middleton, Wilkinson, and Tork properties.

Camp property.—One mile north of Livingston, on the A. H. Camp farm, from 5 to 12 feet of clay gravel are exposed for short distances in gullies west of the Neals Ferry road and to a less degree east of the road. On the Hugo Shipley place, a half mile from the road, a veneer of gravel covers the top of some of the hills and has been scraped up and used in road construction. Similar gravel is common in this part of the county, but it is rarely more than a foot or two in thickness.

Williams property.—On the John Williams place, 2½ miles east of Livingston, 6 feet of coarse quartz gravel outcrop in cuts on the same road and have differing amounts of clay above and below. A short distance west, 3 feet of similar gravel occur near a small branch. Gravel is exposed in the last cut on the Rome road just east of the Foster's Mill-Livingston road and also on the Foster's Mill road, a quarter of a mile south of Livingston.

Between Foster's Mill and Melson, on the R. B. Sims' plantation, from 2 to 4 feet of silty gravel is found at several points, and has been used in road construction. Sample *T-131* contains 70 per cent coarser than 4 mesh. Good concrete gravel occurs in the bed of Cedar Creek at Foster's Mill, and also a foot or two is found above the stream.

Woodward Creek.—In the northeast part of the county, Woodward Creek has a large amount of chert gravel, suitable for concrete aggregate. On the Rome-Plainville road, 2 miles south of Plainville, the stream is 20 feet wide, and a broad bottom has permitted the accumulation of sand, chert, and shale gravel. Sand probably exceeds 50 per cent of the total, and the deposit covers three-quarters of an acre at this point, with lesser areas above and below on the same stream. The gravel is trucked to various points in Floyd and Gordon counties for use in concrete construction work and for construction in Plainville. Sample *T-145*, from this deposit, has a fineness modulus of 4.91 and 47 per cent is coarser than 4 mesh. Similar material occurs along the creek at the Southern Railway bridge half a mile to the west.

Gravel is found in Jimmy Long Creek, but it is not as good as that in Dikes Creek. A branch of the creek near the Plainville road, 3 miles north of Rome, has gravel bars and deposits along part of its course.

Oostanaula River.—Sand and gravel occupy the bed of Oostanaula River for most of its course in Floyd County. Gravel and coarse sand are usually found at the mouths of streams, or on submerged banks or islands. A large deposit of good gravel occurs at the mouth of Armuchee Creek for almost a mile below and for several hundred yards above. Excellent sand and gravel also occupies the bed of Armuchee Creek for most of its course.

On Whitmore's Island, 9 miles above Rome, good brick sand is found grading into coarse sand and gravel on the flanks and ends of, and extending above and below, the island in small submerged bars. Wide places along this river, since they cause a slowing-up of the current, have been generally found to contain coarser sand and gravel.

Some bank gravel occurs east of the river, in the northern part of the county, but it is simply a surface veneer rarely over one or two feet thick.

CHERT

Deposits of good road-building chert have accumulated at the bases of Simms, Turnip, Lavender, and John mountains through the weathering of the Fort Payne chert. This chert is usually pockety and quickly pinches out into clay or rock. Small pits have been opened in the material at several places. That showing the best chert is located just behind Howell's store, at Crystal Springs, on the Rome-Summerville road. Similar chert has been mined on the Howell property, a third of a mile south of the store. The chert here is from 1 to 12 feet thick, the fragments ranging from ½ to 6 inches in size and are irregularly angular. This material has more clay than that behind the store at the springs. The pit is leased to the county for road purposes.

The southeast part of the county, near Chulio and Wax, is covered with residual chert, produced from the weathering of the Knox dolomite. A number of pits have been opened in this material for road-building purposes. but it has been found that it is usually pockety and a deposit is quickly worked out. It is rarely a clean chert, but usually contains a large amount of admixed clay.

The streams in this section of the county generally have good amounts of sand and chert gravel, particularly Spring Creek, which is 25 feet at the Cartersville road and has several sand and gravel bars.

MOLDING SAND

Rome.—Molding sand is obtained by the Rome Sand and Gravel Company from a deposit occupying the right bank of Coosa River opposite Nixon's Island and 1½ miles below the company's dock. The deposit occurs on the banks of a small stream that enters the river at this point. The pit covers about 1,000 square feet, but the sand seems to cover several acres. It is 12 to 15 feet thick at the pit, and the section exposed appears to be of practically uniform quality. On exposure it becomes hard, but does not cake badly. The sand is used locally and is shipped to adjoining towns.

Coosa River.—At Neals Ferry, on the bank of Coosa River, are good exposures of what seems to be good, fine-grained molding sand. The material ranges from 5 to 10 feet in thickness and is covered by from 2 to 3 feet of silty material. The deposit seems to extend over most of the bottom lands of the river which is 800 feet wide at this place.

GORDON COUNTY

No sand or gravel is commercially exploited in the county. Sand used in construction work in Calhoun had to be shipped from Atlanta. Oostanaula and Coosawatte rivers have large amounts of fine-grained sand in their beds, but little of this is available even for local purposes. Barnett Creek, 8 miles south of Calhoun on the Dixie Highway, has fair amounts of sand and gravel suitable for local purposes.

What appears to be desirable molding sand occupies the bottoms of Coosawatte and Oostanaula rivers, particularly near the junction of creeks with these rivers. The sand is found most conveniently near the Resaca-Calhoun road close to the Western & Atlantic Railroad.

MURRAY COUNTY

No sand or gravel has been shipped from Murray County, although the streams afford adequate supplies for all local purposes.

Chatsworth.—A fine-grained sand which has collected in small deposits on the Ogletree and Childers farms along the road from Spring Place to Chatsworth has been used for construction work in Chatsworth and other nearby places.

In the southern part of the county, Holly Creek and its tributaries have fairly good sand in small deposits along its course. A fine-grained sand occupies the bed of Coosawatte River, and coarser material is associated with the mouths of creeks emptying into the river. Molding sand occurs in the river bottoms covered by from 6 to 30 inches of fine, loamy sand.

Mill Creek.—Along most of Mill Creek are small bars of coarse sand and gravel suitable for local work. Natural aggregate from this creek has been used in the construction of a number of concrete bridges in the county and has been found very satisfactory.

In Conasauga River, sand bars occur at intervals. One of the best in the county is just north of Lower Kings Bridge.

PICKENS COUNTY

No sand or gravel has been commercially produced in Pickens County. The streams, however, usually have plenty for local needs, but it is frequently hard to get at it.

Long Swamp Creek.—Small bars of coarse brown sand occupy the bed of Long Swamp Creek from the marble quarries to Etowah River. These bars usually contain from 50 to 500 cubic yards of sand. At Marble Hill where the east fork of the creek is 30 feet wide, the sand is about 2 feet thick in the stream bed and is underlain by gravel a foot in thickness which in turn lies upon blue clay. The sand contains about 15 per cent of schist, marble, and limonite fragments, and a sample (*T-184*) was found to have a fineness modulus of 2.99 and 90 per cent coarser than 48 mesh. The organic matter color value is 800. The sand is brown and has 1 per cent coarser than ½ inch. The coarse particles are mostly schist fragments.

In the bottom lands of Long Swamp Creek, quartz gravel which lies on the bed rocks, is from 2 to 10 feet thick. Although this gravel is very good, it is generally covered by from 5 to 10 feet of gray, fine-grained, loamy sand. Gravel is also found on the hills along the stream, but it usually is only a veneer a few inches thick.

Payne property.—A deposit of remarkably pure sandstone, known as the "Rhodes Silica Deposit," is located 5 miles southwest of Jasper and a little over 4 miles from the Louisville & Nashville Railroad. According to Veatch[1] the principal exposure of the sandstone bed shows 8 feet of almost pure white sandstone. The deposit is massively bedded and jointed, fine-grained, and sufficiently friable to permit of easy crushing. Iron occurs in the rock as an oxide film in the joint and bedding places and as scattered cubes of pyrites, which have in some places altered to limonite, but it is not in sufficient quantities to harm the rock for use in high-grade glass manufacture. No accurate estimate of the tonnage of the deposit could be obtained from the exposures, but it is likely from its origin that it is extensive.

Analyses of sandstone from "Rhodes Silica Deposit," Pickens County

Constituents	1	2
Volatile matter	0.10	0.08
Iron oxide (Fe_2O_3)	0.008	0.03
Alumina (Al_2O_3)	0.11	0.07
Lime (CaO)	0.07	---------
Silica (SiO_2)	99.75	99.82

1.—Analysis by W. Simonson, Cincinnati, Ohio.
2.—Analysis by Dr. Edgar Everhart, of purest rock collected by Otto Veatch.

1 Veatch, Otto, Unpublished report of Georgia Geol. Survey, 1907

POLK COUNTY

The streams of that part of Polk County in the Crystalline area have fair amounts of sand, but those of the northern part of the county, underlain by Paleozoic rocks, have much less sand and more gravel. No sand or gravel is produced commercially in the county.

Cedartown.—Big Cedar Creek west of the town has good, coarse-grained concrete sand along its banks and in the stream bed, but most of that near Cedartown has been used, and as a result sand for local use is now shipped in from Rome or South Georgia.

Euharlee Creek.—Euharlee Creek, near Portland station, has some gravel and also a little sand and gravel near Rockmart. Sand is also found in this creek near Aragon, and both sand and gravel occur in Fish Creek. The best sand occurs in a branch of Euharlee Creek, one mile north of the junction with Fish Creek. Chert gravel used on the roads in the vicinity, is found on the hills near Aragon and is derived from the weathering of the Chickamauga limestone.

In the northwest part of the county, stream beds from 5 to 12 feet wide showed good sand and some chert gravel. Little Cedar Creek has the most sand.

Quartzite.—Weisner quartzite composes Indian Mountain in the extreme northwest part of the county. The quartzite is usually composed of coarse, rounded grains, but does not appear sufficiently pure for the manufacture of any but the cheaper grades of glass.

WALKER COUNTY

Sandstone occurs in large amounts in the Walden, Lookout, and Rockwood formations in Walker County, but none of it is pure enough to warrant development for glass manufacture. Sand and gravel in the county are confined to the streams or else to the chert gravel which occupies large areas in the county. No sand or gravel is shipped.

Lafayette.—Chattooga River, just west of Lafayette, is 15 feet wide and has angular chert gravel with a few rounded quartz pebbles from ¼ to 2 inches in size. Coarse sand composes 40 per cent of the mixture. In Dry Branch from 5,000 to 8,000 cubic yards of chert gravel with about 35 per cent sand occur 2½ miles southeast of Lafayette.

West Armuchee Creek, 3 miles west of Villanow, has considerable sand and gravel, but in East Armuchee Creek, just west of Villanow, the bed is muddy. East of Villanow, in branches of this stream, particularly Dry Branch, one mile from Villanow, excellent gravel and sand occur. Sample *T-155* has a fineness modulus of 6.01 and 69 per cent retained on the 4-mesh sieve.

CHERT

The cherty area of the county coincides with the distribution of the Knox dolomite. The largest belt is 4 miles wide and extends through the county east of Lafayette and includes Peavine Ridge. Missionary Ridge occupies another large belt in the western part of the county.

A number of pits have been opened in this material throughout the county for road purposes. The largest is on the Villanow road, 1¼ miles east of Lafayette and covers a half acre. The face is 40 feet high and the chert fragments, which range from a fraction of an inch to 5 or 6 inches in diameter, are cemented with clay. The chert is red, gray, and yellow, but mostly white and requires breaking down with a pick from above. This material is used on the streets of Lafayette and on the county roads.

Middle Chickamauga Creek probably has more chert gravel than any other stream in the county. A large deposit, containing over a hundred carloads, occurs at Catlette, near Haywood's store. The chert is angular and from ½ to 6 inches in size. Similar material occurs in small branches on the Catlette-Rock Springs road.

Rossville.—In the northern tongue of the county, the chert area forks at a point 3 miles east of Eagle Cliff, the narrow, western strip running up the western spur of Missionary Ridge and the eastern strip continuing along Missionary Ridge to the Tennessee line, one mile east of Rossville.

Good chert may be found along the Central of Georgia Railway from Lytle to Missionary Ridge. On the J. R. McFarland property, at the public road just south of Missionary Ridge, is a large deposit of good clay bonded chert covering several acres. The angular chert fragments range from ¼ inch to 3 inches. Layers of white and pink clay occur between the chert. The material is used on the county roads and appears to give desirable results.

MOLDING SAND

Rossville.—Four and a quarter miles south of Rossville, on the J. R. McFarland property close to the Central of Georgia Railway, is a red, clayey sand containing some chert and coarse rounded grains. A small pit has been opened in the deposit and the sand has been used for foundry purposes in Chattanooga.

One mile south of Blowing Springs, west of the Chattanooga Valley road, is a deposit of red, clayey sand, used in Chattanooga for molding purposes. The face of a small pit opened in the deposit is 15 feet high and a quarter acre has been uncovered. Some chert and coarse grains are found in the molding sand, and it has a tendency to cake hard when exposed. The iron content is high, indicating a low fusing point.

Crutchfield property.—A large molding sand pit is situated on the Crutchfield property, 1½ miles north of Flintstone. It covers several acres, and the sand ranges from 3 to 6 feet in thickness and is a flood-plain deposit of a small creek flowing through the property. The sand has been shipped in large quantities to Chattanooga and adjoining points for foundry work, but when visited in September, 1919, it was found that none had been shipped that year.

Morse Brothers.—On the Chattanooga Valley road, 3 miles south of Chattanooga, Morse Brothers formerly shipped molding sand to Chattanooga. The deposit is of flood-plain origin, resulting from the overflow of Chattanooga Creek. The sand is fine-grained and apparently well suited for molding purposes.

WHITFIELD COUNTY

Pure, white sandstone of the Rockwood formation is prominently exposed on Chattoogata Mountain. Molding sand is shipped from small pits near Dalton at the present time, and crushed sandstone was formerly shipped from Rocky Face Mountain, above Tunnel Hill, but no building sand or gravel is being produced.

Mill Creek.—Along Mill Creek, on the properties of Frank McCutcheon and Edward White, especially near where the Dixie Highway crosses the stream, are deposits of excellent coarse concrete sand and brick sand. The sand occupies both the bed of the stream and the banks, and it is hauled to Dalton and other points for local construction uses. Sample *T-167*, typical of the concrete sand in this creek, has a fineness modulus of 4.43 and 34 per cent is coarser than the 4-mesh sieve. A finer-grained sand suitable for brick and plaster mortar occurs in small quantities along the stream banks.

Smith property.—Good molding sand has been deposited by Mill Creek in its bottom lands on the farm of Mrs. J. H. Smith, on the Cleveland road, 1½ miles north of Dalton. The sand is found all along the creek on both sides of the Southern Railway. When mining of the sand was begun about 1895, it was obtained a quarter of a mile west of the railroad, where it was mostly the No. 1 black stove-plate grade. At present the pits are located just east of the Cleveland road, where three grades of molding sand can, with careful selection, be obtained. There are two pits which cover about an acre between them.

Section at large molding sand pit, Mrs. J. H. Smith property, Dalton

	Feet	Inches
Gray, silty soil		6-8
Brown to red and yellow molding sand. The different grades merging irregularly into each other laterally and vertically	2–3	
Fine-grained, brick sand	2	

In some places a coarser sand suitable for concrete work underlies the molding sand. The molding sand consists of two grades of No. 1 stove-plate, the red and the dark brown, and No. 2 molding sand for coarser castings. The sand is hauled a short distance to the railroad where it is piled in a small frame shed or else loaded on cars on a small switch.

Sand similar to that on the Smith place is found on the Porter Moore property further west on Mill Creek, but farther from the railroad.

SANDSTONE

A very pure sandstone belonging to the upper part of the Rockwood formation outcrops along the top of the Chattoogata Mountain. The white sandstone makes up the upper 60 or 70 feet of that portion of the mountain known as Rocky Face, and it also outcrops for a short distance at the north end of the mountain, south of the gap. (Plate XX-B.)

An attempt was made about 1915 to crush the sandstone and make glass of it. For this purpose a company was formed, and some of the rock was shot down from that part of the mountain controlled by the C. L. Hardwick Banking Company of Dalton. It was crushed in a rock crusher installed part way up the west side of Rocky Face.. It is understood that several carloads were shipped. Where the rock was quarried the sandstone dips at an average of 40° to the east and strikes about N. 20° E. The rock forms heavy bedded white ledges with well-defined bedding planes, permitting the rock to be easily quarried. An analysis of the rock (No. 1804) at the quarry site, made a few years ago by Dr. Edgar Everhart gave the following results:

Analyses of sandstone from Rocky Face, Whitfield County

Constituents	T-172	No. 1804
Moisture at 100° C	0.15	---------
Loss on ignition	0.79	0.46
Soda (Na_2O)	0.44	---------
Potash (K_2O)	0.56	---------
Lime (CaO)	0.00	---------
Magnesia (MgO)	0.11	---------
Alumina (Al_2O_3)	2.07	---------
Ferric oxide (Fe_2O_3)	1.09	0.25
Titanium dioxide (TiO_2)	0.48	0.12
Silica (SiO_2)	97.91	94.12
Total	98.74	94.95

Glaze property.—The W. B. Glaze property adjoins the Hardwick Banking property on the south and the same geological conditions prevail as to the north. A sample of the sandstone of this property was analyzed and is given in the table above.

TESTS OF PALEOZOIC AREA SANDS

Number	Locality	Percentage coarser than each sieve													Effec. size	Uniformity coefficient	Fineness modulus	Specific gravity	Voids percentage	Weight per cu. ft.	Weight per cu. yd.	Color value of organic matter	Page number of text description	Number
		4	6	8	10	14	20	28	35	48	65	100	150	200										
135	Rome, Oostanaula R.	----	----	----	0.5	0.8	1.3	2.0	3.7	8.3	36.5	67.5	86.8	95.5	.091	2.21	0.79	2.64	49.0	85.0	2295	400	357	135
136	Rome, Etowah R.	----	----	----	0.2	0.4	0.7	1.4	9.5	39.7	78.4	96.5	98.9	99.7	.167	2.49	1.38	2.67	44.8	92.1	2487	560	353	136
138	Rome, Etowah R.	0.4	0.6	0.8	1.0	1.2	1.8	5.3	37.5	76.2	90.5	97.6	99.4	99.8	.211	2.77	1.82	2.69	44.2	93.7	2530	400	353	138
149	Lyerly, bk.	----	----	----	0.1	0.3	3.8	10.1	15.0	22.1	44.6	75.8	92.3	97.1	.110	2.11	1.12	2.67	41.9	95.7	2585	200	349	149
158	Rising Fawn, bk.	----	0.5	0.8	1.3	1.8	2.6	4.3	12.6	38.1	80.5	95.4	97.6	98.8	.169	1.72	1.40	2.63	42.8	93.7	2530	250	351	158
163	Ringgold, bk.	----	----	----	0.1	0.3	0.5	1.9	9.4	31.4	56.6	70.4	78.6	88.3	.063	4.21	1.04	2.64	36.5	105.0	2835	trace	347	163
176	Emerson, bk.	----	----	----	0.1	0.2	0.3	0.5	1.6	7.9	47.9	85.3	95.5	99.3	.128	1.76	0.94	2.67	45.6	88.7	2395	50	345	176
177	Emerson, bk.	----	0.3	1.0	3.2	7.9	21.0	44.4	72.6	87.8	98.5	99.2	99.2	99.6	.271	2.34	2.40	2.67	39.7	100.2	2705	150	345	177
179	Cartersville, Etowah R.	----	----	0.1	0.2	0.5	2.3	12.3	54.1	78.4	90.8	97.2	98.7	99.6	.214	2.23	1.89	2.69	45.5	90.6	2538	100	346	179
181	Canton, cr.	13.2	17.9	22.0	30.5	42.3	56.7	72.6	85.1	91.5	95.7	98.4	99.0	99.6	.323	3.91	3.40	2.66	38.8	101.5	2141	200	289	181
182	Canton, cr.	0.3	0.4	0.4	0.4	0.8	1.6	5.0	20.0	50.0	76.1	92.1	97.4	99.4	.155	2.17	1.49	2.67	47.7	89.4	2413	125	289	182
184	Marble Hill, bk.	5.9	9.8	14.1	22.2	31.4	43.9	58.8	77.6	90.1	96.5	98.5	99.0	99.5	.296	3.17	2.99	2.71	42.4	96.9	2616	800	360	184

NOTE: R=river, cr=creek, bk=bank.

TESTS OF PALEOZOIC AREA GRAVELS

Number	Locality	Percentage coarser than each sieve																Fineness modulus	Percent of clay washed out	Page number of text description	Number
		1¼	¾	½	4	6	8	10	14	20	28	35	48	65	100	150	200				
137	------------------------------	30.9	37.5	45.2	54.2	57.4	59.0	60.7	62.2	64.6	69.2	80.5	90.1	97.2	99.4	99.9	99.9	5.49	------	353	137
139	Rome, bk.	13.3	38.3	52.3	86.7	88.7	89.6	90.4	91.2	92.5	94.3	96.4	97.8	98.8	99.5	99.8	99.9	6.63	3.3	354	139
142	Coosa, bk.	27.9	43.3	52.9	66.3	68.1	70.5	71.6	73.5	77.2	81.0	88.1	93.7	96.3	98.3	99.1	99.5	6.06	9.6	355	142
143	Rome, pit	17.5	32.9	47.4	74.2	79.8	83.3	86.0	88.1	90.5	93.9	97.3	98.9	99.5	99.8	99.9	100.0	6.36	7.4	354	143
144	Pinson, cr.	24.1	41.4	51.6	67.2	72.0	76.4	80.8	84.1	86.9	89.8	93.5	95.7	97.4	98.1	98.7	99.3	6.28	------	------	144
145	Plainsville, cr.	11.7	15.6	23.4	47.2	55.0	59.3	63.3	66.5	69.9	75.2	84.1	92.5	97.5	99.1	99.5	99.8	4.91	------	357	145
146	Rome, cr.	32.9	59.8	72.3	84.9	87.2	88.5	89.8	90.8	92.0	93.7	96.0	98.0	99.1	99.6	99.7	99.9	5.49	------	355	146
155	Villanow, cr.	19.3	33.5	45.7	68.6	73.5	75.7	78.2	80.0	82.2	85.2	90.0	94.6	97.2	98.5	99.1	99.4	6.01	------	362	155
167	Dalton, cr.	6.1	9.8	14.8	33.9	42.6	49.6	56.3	61.3	66.3	74.7	88.8	94.8	97.3	98.4	99.1	99.5	4.43	------	363	167
175	Adairsville, cr.	4.4	14.5	22.7	51.0	64.1	74.1	83.4	89.7	94.3	97.3	99.0	99.4	99.6	99.7	99.8	99.9	5.53	------	347	175

BIBLIOGRAPHY OF SAND AND GRAVEL

OCCURRENCE

Beadnell, H. J. L., Sand dunes of the Lybian desert: Geographical Magazine, Vol. 35, pp. 379-392, 1910.

Condra, G. E., Sand and gravel resources and industries of Nebraska: Nebraska Geol. Survey, Vol. 3, pt. 1, pp. 1-206, 1911.

Cornish, Vaughan, On the formation of sand-dunes: Geographical Jour., Vol. 9, pp. 278-302.

Dake, C. L., The sand and gravel resources of Missouri: Missouri Bur. Geol. and Mines, Vol. XV, 2d ser., 1918.

Gilbert, G. K., Transportation of debris by running water: U. S. Geol. Survey. Prof. Paper 86, 263 p., 1914.

Hitchcock, A. S., Controlling sand dunes in the United States and Europe: Natl. geographic magazine, Vol. 15, pp. 43-47, 1904.

Logan, W. N., Structural materials of Mississippi: Mississippi Geol. Survey, Bull. 9, 1911.

Nelson, W. A., Some building sands of Tennessee: Tennessee Geol. Survey, Resources, Vol. 2, pp. 389-397.

Sand, its occurrence, properties and uses: A bibliography, Carnegie Library of Pittsburg, 1918.

Shaler, N. S., Phenomena of beach and dune-sands: Bull. Geol. Society of America, Vol. 5, pp. 207-212, 1894.

Simonds, F. W., Floating sand; an unusual mode of river transportation: American Geologist, Vol. 17, pp. 29-37, 1896.

PHYSICAL PROPERTIES

Chapman, C. M., Importance of testing sands: Eng. Record, Vol. 66, pp. 401-402, 1912.

Results of experiments upon effect of sea water on the tensile strength of various mixtures of cement and sand: Natl. Assoc. Cement Users Proc., Vol. 6, pp. 172-174, 1910.

Testing of sand for use in concretes: I, field and laboratory practice; II, computing and using results: Eng. News, Vol. 71, pp. 306-310, 554-558, 1914.

Testing sand for use in concrete and cement mortar: Eng. Record, Vol. 65, pp. 465-466, 1912.

Chapman, C. M., and **Johnson, N. C.**, Economic side of sand testing: Eng. Record, Vol. 71, pp. 734-737, 1915.

Condit, D. D., Petrographic character of Ohio sands with relation to their origin: Jour. Geology, Vol. 20, pp. 152-163, 1912.

Feret, R., Essais de divers sables pour mortiers: Eng. Record, Vol. 34, p. 311, 1896.

Free, E. E., Proposed study of concrete sands; possible explanation of the defective sands: Eng. News, Vol. 67, pp. 1024-1025, 1912.

Freeman, J. R., Proposed study of concrete sands; defective concrete sands: Eng. News, Vol. 67, pp. 1022-1024, 1912.

Grabau, A. W., On the classification of sand grains: Science, Vol. 56, n. s. Vol. 33, pp. 1005-1007, 1911.

Greenman, R. S., Practical tests of sand and gravel proposed for use in concrete: Amer. Soc. Test. Mat. Proc., Vol. II, pp. 515-520, 1911.

Tests of natural concrete aggregates: Amer. Soc. Test. Mat. Proc., Vol. 13, pp. 828-833, 1913.

Griesenauer, G. J., Loam and clay in sand for concrete: Eng. News, Vol. 51, p. 413, 1904.

Hain, J. C., Mortar sand: Natl. Assoc. Cement Users Proc., Vol. 1, pp. 42-50, 1905.

Hatt, W. K., and **Scofield, H. H.**, Laboratory manual of testing materials: 135 p., 1913, McGraw.

Jewett, J. Y., Some sand experiments relating to per cent of voids and tensile strength: Amer. Soc. Test. Mat. Proc., Vol. 6, pp. 405-411, 1906.

King, F. H., Principles and conditions of the movements of ground water: U. S. Geol. Survey Ann. Rept. for 1897-98, pt. 2, pp. 59-294, 1899.

Laclotre, Influence de L argile contenue dans les sables sur la resistance des mortiers: Annales des ponts et chaussees, memoires, ser. 9, Vol. 36, pp. 257-270, 1916.

Montgomery, C. M., Testing of sand for concrete: Eng. News, Vol. 71, pp. 804-805, 1914.

Phillips, C. E. S., Electrical and other properties of sand: Nature, Vol. 84, pp. 255-261, 1910.

Reinecke, L., Non-bituminous road materials: Economic Geology, Vol. 13, pp. 557-597, 1918.

Sherzer, W. H., Criteria for the recognition of the various types of sand grains: Bull. of Geol. Soc. America, Vol. 21, pp. 625-662, 1910.

Smith, F. P., Essential physical properties of sand, gravel, slag and broken stone for use in bituminous pavements: Better roads and streets, Vol. 6, pp. 18-21, 1916.

Standard terminology for filter and concrete sands: Eng. Record, Vol. 71, p. 671.

Thompson, S. E., Impurities in sand for concrete: Amer. Inst. Civil Eng. Trans., Vol. 65, pp. 250-273, 1909.

Field examination of concrete sand: Concrete-cement age, Vol. 6, pp. 303-305; Vol. 7, pp. 73-75, 156-157, 1915.

Tomlinson, C. W., Method of making mineralogical analysis of sand: Amer. Inst. Mining Eng., Bull. 101, May, 1915, pp. 947-956.

Whinery, S., Table giving voids in sand, based on weight method: Eng. News, Vol. 71, p. 572, 1914.

SAND FOR CONCRETE, MORTAR AND OTHER STRUCTURAL PURPOSES

Abrams, D. A., The design of concrete mixtures: Struct. Mat. Res. Lab., Lewis Inst., Chicago, Ill., Bull. 8, 1919.

Baker, I. O., Sand for mortar: Brickbuilder, Vol. 8, pp. 116-117, 1899.

Fuller, W. B., and **Thompson, S. E.**, Laws of proportioning concrete: Amer. Soc. Civil Eng. Trans., Vol. 59, pp. 67-143, 1907.

McNeilly, R. H., Sand for concrete and cement mortar should have "jump" in grading: Eng. Record, Vol. 72, pp. 659-662, 1915.

Okey, F. M., Good concrete and how to get it: Municipal Eng., Vol. 36, pp. 293-296, 1909.

Owens, J. S., Concrete aggregates: Concrete and constructional Eng., Vol. 4, pp. 40-46, 1909.

Sabin, L. C., Cement and concrete: 507 p., 1905. McGraw.

Specifications for sand and stone for concrete: Eng. Record, Vol. 59, p. 587, 1909.

Taylor, F. W., and **Thompson, S. E.**, Treatise on concrete, plain and reinforced: Ed. 3, 885 p., 1916. Wiley.

What percentage of clay is it safe to permit in sand for cement mortar? Eng. News. Vol. 57, p. 620, 1907.

GLASS SAND

Boswell, P. G. H., Memoir on British resources of sand suitable for glass-making, with notes on certain crushed rocks and refractory materials: 92. p., 1916.

Sands for glass making, with special reference to optical glass: Sci. Am. Suppl. Vol. 84, pp. 310-311, 1917.

Burchard, E. F., Glass sand of the middle Mississippi basin: Contributions to economic Geol. Survey, Bull. 285, pp. 459-472, 1905.

Requirements of sand and limestone for glass making: Contributions to economic geology, U. S. Geol. Survey Bull. 285, pp. 452-458, 1905.

Buttram, Frank, Glass sands of Oklahoma: Oklahoma Geol. Survey, Bull. 10, 91, p., 1913.

Fettke, C. R., Glass manufacture and the glass-sand industry of Pennsylvania: Pennsylvania Top. and Geol. Survey, Rept. XII, 1919.

Frink, R. L., Effects of alumina on glass: Am. Ceramic Soc. Trans., Vol. II, pp. 99-102, 1909.

Some fallacies and facts pertaining to glass making: Am. Ceramic Soc. Trans., Vol. II, pp. 296-317, 1909.

Kummel, H. B., and **Gage R. B.**, Glass-sand industry of New Jersey: New Jersey Geol. Survey, Ann. Rept. for 1906, pp. 77-96, 1907.

Peddle, C. J., British glass-making sands, pt. 1: The substitution of some British sands for foreign sands in the manufacture of high-grade glass: Jour. Soc. of Glass Technology, Vol. 1, pp. 27-59, 1917.

Rosenhain, Walter, Glass manufacture, 264 p., 1908. Van Nostrand.

MOLDING SAND

Eckel, E. C., Molding sand; its uses, properties and occurrence: New York Museum Ann. Rept. for 1901, p. r 91-r 96, 1901.

Field, H. E., Molding sands: Sci. Amer. Suppl., Vol. 61, pp. 25346-25347.

French sand: Brass World and Platers' guide, Vol. 13, p. 307, 1917.

International Correspondence Schools, Scranton, Pa., Foundry appliances: International Library of Technology, Vol. 142, section 76-77, 1916.

Kummel, H. B., and **Hamilton, S. H.**, Report on some molding sands of New Jersey: New Jersey Geol. Survey Ann. Rept. for 1904, pp. 187-246, 1905.

Moldenke, Richard, Some latter-day problems of the foundry: Sci. Amer. Suppl., Vol. 84, pp. 246-247, 1917.

Muntz, G., and **Roubieu, E.**, Steel foundry sand: Foundry, Vol. 45, pp. 312-315.

Newland, D, H., Albany molding sand: Amer. Inst. Metals, Trans., Vol. 9, pp. 404-408, 1915.

Ries, Heinrich, and **Rosen, J. A.**, Foundry sands: Michigan Geol. Survey Ann. Rept., pp. 33-85, 1908.

Ries, Heinrich, Laboratory examination of molding sand: Foundry, Vol. 28, pp. 327-343, 1906.

Relative values of the physical and chemical examinations of molding sands: Foundry, Vol. 32, pp. 224-226, 1908.

Robeson, J. S., Core sands: American Foundrymen Assoc. Trans., Vol. 14, pp. 100-107, 1906.

Searle, A. B., Testing of molding sands: Eng. magazine, Vol. 44, pp. 103-106, 1912.

PRODUCTION

A sand blast and steel molding sand plant: Foundry, Vol. 43, pp. 36-37-41, 1915.

Automatic sand dryer: Electric Railway Jour., Vol. 46, p. 455, 1915.

Bowles, Oliver, Sandstone quarrying in the United States: U. S. Bureau of Mines, Bull. 124, 135 p., 1917.

Centrifugal dredging pump applied to production of sand and gravel: Concrete-cement age, Vol. 7, pp. 191-192, 1915.

Crain, G. D., Jr., Design and construction features of a sand and gravel storage plant: Concrete, Vol. 8, pp. 219-221, 1916.

Dennis, F. J., Modern methods of gravel excavation: Mining and Sci. Press, Aug. 3, 1912.

Digging gravel from river bed by a cableway excavator: Contractor, Aug. 15, 1916.

Digging gravel with a big revolving shovel: Excavator Eng., Sept., 1914.

Dragline cableway is an effective trap for sand and gravel plants: Eng. Record, June 5, 1915.

Dull, R. W., Preparation of rock products: Jour. Western Soc. Eng., Vol. 22, pp. 479-485, 1917.

Sand and gravel washing plants: Concrete-cement age, Vol. 2, pp. 129-131, 1913.

Efficient truck loader: Rock products and building materials, Vol. 19, April 7, 1917, p. 28.

Electricity in sand and gravel plants: Elect ical review and western electrician, Vol. 67 pp. 599-602, 1915.

Gillette, H. P., Handbook of cost data: McGraw-Hill Book Co., N. Y., 1854 p., $5.00.

Haight, C. M., Steam shovel operation: Eng. and Mining Jour., Feb. 14, 1914.

Handbook of steam shovel work: Bucyrus Co. of Milwaukee, Wis., 1911, 374 pp.

Hauling sand and gravel with a motor truck: Eng. Record, Vol. 66, p. 473, 1912.

Hawkins, C. L., New sand-drying plant of the United Railway Company of St. Louis: Jour. of the Assoc. of Eng. Societies, Vol. 48, pp. 61-67, 1912.

Hydraulic hopper dredge with unloading machinery: Eng. News Vol. 76, p. 1211, 1916.

Modern gravel excavation: Excavation Eng., Dec., 1916.

Moving sand by pumping: Eng. News, Vol. 72, pp. 384-385, 1914.

Plant of the Atwood Davis Sand Co., Beloit, Wis.: Excavating Eng., Vol. II, pp. 409-412, 1915.

Portable gravel digging and screening plant: Eng. and Contracting, Vol. 37, p. 600, 1912.

Portable sand and gravel washer for contractor's use: Eng. and Contracting, Vol. 41, p. 700, 1914.

Prelini, Charles, Dredges and dredging: 279 pp., 1911. Van Nostrand.

Simple sand and gravel washing device: Brick and Clay Record, Vol. 51, pp. 137-138, 1917.

Smith, A. E., Pumping and loading sand: Electrical world, Vol. 66, pt. 1, pp. 467-468, 1915.

Speir, H. F., Methods employed in connection with the reduction, milling, and shipment of quartz, flint rock or silica sand: Amer. Ceramic Soc. Trans., Vol. 13, 00. 326-331, 1911.

Stripping a gravel pit with an electric revolving shovel: Excavating Eng., June, 1914.

The drag-line excavator for gravel pit service as used by the Badger Cement Block and Paving Co.: Excavating Eng., Nov., 1912.

Welch, F. M., Importance of location to the success of sand and gravel washing plants: Rock Products and Building Materials, Vol. 18, Sept., 22 1916, p. 40.

Problems and progress in sand and gravel washing: Rock products and building materials, Vol. 17, Jan. 7, 1916, pp. 33-35.

Wilms, W. H., Operations of sand and gravel plants: Eng. News, Vol. 72, pp. 962-966, 1008-1012, 1914.

Stripping of gravel pits by hydraulic methods: Railway Age Gazette, June 18, 1915.

MISCELLANEOUS

Bohm, C. R., Monazite sand: Eng. and Mining Jour., Vol. 81, p. 842.

Boswell, P. G. H., Sands used in metallurgical practice, with comparative notes on those used in glass manufacture: Jour. Society of Chemical Industry, Vol. 36, pp. 753-758, 1917.

Brady, F. W., White sands of New Mexico: Sci. Amer. Suppl., Vol. 59, p. 24649, 1905.

Burgess, Philip, Mechanical analysis of sands: Jour. Amer. Water Works Assoc., Vol. 2, pp. 493-500, 1915.

Carr, W. F., Railway sand experience: Electric Railway Jour., Vol. 45, p. 143, 1915.

Day, D. T., and **Richards, R. H.**, Investigation of black sands from placer mines: Contributions to economic geology, U. S. Geol. Survey Bull. 285, pp. 150-164.

Ells, S. C., Preliminary report on the bituminous sands of northern Alberta: Mines Branch, Canada Dept. of Mines, 92 p., 1914.

MacKenzie, G. C., Magnetic iron sands of Natashkwan, County of Saguenay, Province of Quebec: Mines Branch, Canada Dept. of Mines, 57 pp., 1912.

Parr, S. W., and **Ernest, T. R.**, A study of sand-lime brick: Illinois Geol. Survey, 1911

Patton, F. E., Use of sand on locomotives: Railway age gazette, mechanical edition, Vol. 87, p. 594, 1913.

Peppel, Samuel Vernon, Manufacture of artificial sandstone or sand-lime brick: Ohio Geol. Survey, Bull. 5, 1905.

Rankin, K., Sanding rails: Coal Age, Vol. II, p. 946, 1917.

APPENDIX A

SAP BROWN

It has been thought well to include in this report a description of the sap-brown deposits of the state, since the material is essentially a sand cemented by precipitated azo-humic and other organic acids. The writer is indebted to Dr. J. D. Haseman, of Atlanta, who has been active in prospecting and developing sap brown in Florida and Georgia, for the information regarding the material and the deposits.

Sap brown ore is a silica sand with smaller amounts of a great variety of rarer, dark-colored minerals, and cemented into a fairly hard, black, or dark-brown material, by from 8 to 19 per cent of azo-humic acids and other organic matter soluble in alkalies. The cementing material is used to make Van Dyke brown and sap brown dyes and has been derived from the precipitation of azo-humic acid dissolved in swamp waters by iron salts or sea-water. Prior to 1914, Germany supplied all the sap brown used in the United States, but during the war it was necessary to find a source in this country. A small plant has been in operation at Haseman, Florida, where a small deposit of about 100,000 tons of the ore occurs.

A very large deposit, estimated by Dr. Haseman at more than 2,000,000 tons, has recently been discovered by him in Charlton County along the Georgia Southern & Florida Railway, 3 miles west of St. George, and on a sand hill on the east flank of Trail Ridge. The deposit is located in lot 273, first land district, and is owned by the American Sap Brown Company. The ore outcrops in a ditch in the railroad cut for a distance of over 3,000 feet from 3 to 6 feet below the railroad grade. Ore averaging 2 or more feet in thickness is said to underlie from 250 to 260 acres, with an overburden of loose, or partially indurated sand, averaging 10 feet in thickness. In places, as little as 5 feet, and as much as 12 feet of cover, occurs. The overburden is less on the flanks of the deposit than at its center.

Typical section of sap-brown deposit, three miles west of St. George[1]

	Feet	Inches
White to gray, loose, quartz sand	1–2	
Yellow to reddish-brown, indurated, clayey sand or "hard pan," with iron oxide and humic acid cement		8–18
Gray to brown quartz sand, stained with humic acid	6	
Sap brown ore	5	
White quartz sand	10	

1. Section furnished by Dr. J. D. Haseman.

In general, the ore follows the contour of the hill, indicating a relation between the ore and the ground water. It thins out on all sides into brown sand containing humic acid and organic fragments too low in soluble material for treatment. The contact of the ore and the white sand below is sharp in places, but usually they grade into each other in a distance of 2 to 5 inches. The upper contact is more gradual. Hard, parallel bands, or layers, from 2 to 4 inches thick and rich in sap brown, extend through the deposit dipping in a general northwestward direction. In places these bands extend above or below the main deposit for several feet into the barren sand. The sand composing these rich bands is particularly rich in the dark, rarer mineral grains, of which 14 varieties have been identified.

The dye material, or sap brown, which cements the sand, is the amount of organic matter soluble in alkali. Several analyses of the material made in the Georgia Geological Survey Laboratory and elsewhere, showed contents of soluble organic matter ranging from 9.2 to 17.98 per cent. Some of these analyses are submitted below.

Analyses of sap brown from property of American Sap Brown Company

Constituents	No. 1 Hard	No. 3 Hard
Moisture at 100° C	7.82	7.01
Loss on ignition	9.62	7.67
Silica and insoluble matter	82.52	85.32
Dyestuff soluble in alkali and insoluble in acid	8.21	6.21
Mineral matter insoluble in acid and alkali	80.49	81.16

The high-grade ore is generally distinguished from the sand stained with humic acid and organic fragments by its hardness and black or dark-brown color. The low-grade material is a dull, rusty, reddish-brown when dry, while the true sap brown is clear, black or brown, sometimes with shining crystal faces. The ore usually goes to pieces when dry or exposed to the weather and becomes darker and loses some of its sap brown content. When wet the best ore is usually very hard. The upper part of the ore is usually of lower grade than the bottom.

ORIGIN

The sap brown is believed to be formed by the precipitation of azo-humic acid and other organic acids dissolved in stream or ground water by iron salts, sea-water, or through electrolytic action induced by the rare mineral grains which are generally so much more abundant in the richer portions of the deposit. The precipitated sap brown cements the sand grains together and forms an impervious hard-pan. The position of the water table appears to have influenced the deposition of the sap brown. After one impervious bed was lain down, the height of the water would be increased and another band might be deposited above the first. The position of the indurated iron oxide bank 6 feet above the ore is probably due to the position of the new water level after the deposition of the sap brown. It is the opinion of Dr. Haseman that the deposition of the material has been quite recent, within the last few hundred years, particularly since a spar from a modern ship was discovered beneath the Florida deposit.

Sap brown can best be mined with a steam shovel. The ore is then conveyed to a pebble mill, from which it is passed to classifiers, thickeners, and dryers, and the product sold as Van Dyke brown. For the manufacture of sap brown the thickened product is dissolved with soda ash, and the material shipped as an organic sodium salt. The price of the finished product in 1914 was 2 to 3 cents a pound, but in 1920 it was bringing 6 cents a pound.

OTHER DEPOSITS

A deposit of sap brown ore, averaging 8 inches or more in thickness ness, and with a cover of from 15 to 30 feet, most of which is usually below water, occurs in Trail Ridge at the eastern border of the Okefenokee Swamp, along the old Suwannee Canal, just east of Camp Cornelia. This deposit is too far from transportation to warrant consideration at present.

Deposits of indurated, brownish sand, resembling sap brown, have been reported by S. W. McCallie, State Geologist, as occurring on Sapelo, Cumberland, and St. Simon islands, off the eastern coast of Georgia, but the material is not a true sap brown, but rather humic acid.

USES

Sap brown and Van Dyke brown are used principally as brown paper dyes, but considerable amounts are also used in the manufacture of paint, wood-stains, and inks, or to mix with aniline dyes. It has recently been shown that due to its nitrogen content of 3 per cent it can be used instead of bone meal or cyanides to case-harden steel.

APPENDIX B

BLACK SANDS OF THE COASTAL ISLANDS

On a number of the islands bordering the Atlantic Coast of Georgia and Florida, black sands have been noted whose content of the rarer minerals is believed sufficiently large to warrant their consideration as commercial deposits.

In 1916[1] a plant was in operation for the mining and separation of the black sands from the beach sands on an island off the northern coast of Florida between St. Johns and North rivers. On the Georgia islands no commercial development has yet been undertaken. The writer is indebted to S. W. McCallie, State Geologist, who has made several trips to the deposits, for the data given herein.

ST. SIMON ISLAND

St. Simon Island is situated just northeast of Brunswick and is reached by boat from that city. The most conspicuous deposit of black sand occurs at the southern end of the island, near the wharf and immediately in front of the lighthouse. These rich strata extend for probably a half mile along the southern point of the island.

Section in front of lighthouse, St. Simon Island

	Feet	Inches
Black sand, will run, in places, as high as 50 per cent of the rarer minerals		12
Black sand, average dark mineral content from 2 to 10 per cent	3	
Quartz sand with a few grains of black minerals	1	

The dark minerals appear to occupy the upper part of the beach sands between the high and low tide marks and are probably a concentration by waves and currents. Further from the sea the black sand is covered by wind-shifted sands to a depth of from 1 to 10 feet.

Analysis of black sand from St. Simon Island

Lime (CaO)	0.00
Magnesia (MgO)	0.00
Alumina (Al_2O_3)	0.00
Ferric oxide (Fe_2O_3)	7.84
Ferrous oxide (FeO)	11.29
Manganous oxide (MnO)	1.89
Titanium dioxide (TiO_2)	34.40
Phosphorus pentoxide (P_2O_5)	0.18
Silica (SiO_2)	43.12
Zirconium oxide (ZrO)	0.12
Thorium oxide (ThO_2)	0.28
Cerium oxide (CeO_2)	0.53
Total	99.65

1. Liddell, D. M., Eng. and Mining Journal, Vol, 104. pp. 154, 1917

SAPELO ISLAND

Sapelo Island is situated midway between the South Carolina and Florida boundaries and is reached by boat from Darien. The black sand is most prominent a short distance north of the lighthouse at the south end of the island. The sand here is black due to the large content of magnetite and ilmenite. The thickness was not ascertained but the sand appears to be general throughout most of the island, particularly along the beach. The dunes do not appear to have much of the darker sand.

Analyses of black sand from Sapelo Island

Constituents	No. 1	No. 2
Moisture at 100° C	0.18	
Loss on ignition	1.03	
Potash (K_2O)	1.06	
Soda (Na_2O)	1.19	
Lime (CaO)	1.08	.37
Magnesia (MgO)	.12	.17
Alumina (Al_2O_3)	0.91	
Ferric oxide (Fe_2O_3)	0.43	5.16
Ferrous oxide (FeO)	0.86	8.36
Manganous oxide (MnO)	0.32	trace
Titanium dioxide (TiO_2)	5.55	5.23
Phosphorus pentoxide (P_2O_5)	0.49	0.28
Silica (SiO_2)	85.78	80.15
Tin	0.00	
Thorium oxide (ThO_2)	0.24	
Cerium oxide (Ce_2O_3)	0.40	0.18
Zirconium oxide (Zr_2O_3)	0.10	0.08
Chlorine	0.15	
Sulphur	0.11	
Total	99.75	100.90

The natural sample (No. 1) whose analysis is given was taken from the richest part of the deposit, north of the lighthouse, which probably contained from 5 to 6 per cent of the dark minerals. The analysis indicates quartz, ilmenite, magnetite, monazite, and zircon, whose relative abundance is probably in the order given.

ST. GEORGE

Sand similar in mineral content to that on the coastal islands is reported by Dr. J. D. Haseman to be associated with deposits of sap brown on the Georgia & Florida Railway, 3 miles west of St. George in Charlton County. In the sap brown deposits where the dark mineral content is large the sap brown content is also large.

APPENDIX C

SINGING SANDS

During the course of the field work incident to the preparation of this report, the attention of the writer was called to a number of occurrences of "singing" or "whistling" sand. The most prominent example, perhaps, is that at Thunder Spring near Thunder station on the Macon & Birmingham Railroad, 8 miles east of Woodbury. This has been previously mentioned by Mr. S. W. McCallie[1], who has observed a similar phenomenon in the terrace sands along Allapaha River north of Statenville. Dr. R. M. Harper[2] has also noted singing sands in the bars along Cannoochee River, west of Groveland. The writer has also noted singing sands along Ocklocknee River just above the Thomasville-Albany road. In all these cases when the sand was walked over, or when the heels were shuffled in it, or when some of the sand was rubbed gently between the fingers, a sound was emitted similar to that caused by wagon wheels in snow on a cold day, or similar to that produced when a moistened finger is drawn over glass.

The cause of this rather peculiar phenomenon has been variously explained. W. D. Richardson[3] attributed the singing sands of Lake Michigan to a thin film of calcium and magnesium salts precipitated on the sand grains from the waters of the lake. E. O. Fippin[4] believes the circumstance due to the rubbing together of well-rounded and smooth grains which contain a small percentage of moisture formng a thin film around the grains. H. C. Bolton and A. A. Julien[5] in a number of papers have described singing sands from fresh-water and sea beaches and from desert regions in Egypt, Nevada, and elsewhere. Their investigations appear to indicate that the phenomena are due to thin films of air condensed upon the surfaces of the sand grains during gradual evaporation after wetting by sea, lake, river, or rain water.

The diversity of the conditions under which singing sands have been noted leaves the impression that the phenomenon may be induced by any one of several different causes. In most of the cases of singing sands noted along and above Georgia rivers the grains were

1 Georgia Geol. Survey, Bull. 20, p. 157 1913
2 Oral communication
3 The singing sands of Lake Michigan: Science n. s., Vol. 50, p. 493, 1919.
4 More on singing sands: Science, n. s. Vol. 51, p. 64, 1920.
5 Am. Assoc. for the Adv. of Science Proc., Vol. 32, p. 251, 1883; Vol. 33, p. 408, 1884
N. Y. Acad. of Sciences Trans., Vol. 3, pp. 72-76, 97-99, 1884.

quite dry. On the other hand, at Thunder Spring the peculiar crunching sound was easily audible when the sand was rubbed together beneath the water of the spring.

Granulometric analysis of Thunder Spring singing sand, T-103

	Per cent retained on each mesh size										
Mesh size	8	10	14	20	28	35	48	65	100	150	200
Per cent	0.1	0.6	1.8	4.2	10.4	24.4	53.7	84.4	97.8	99.4	99.8

The usual method of determining the amount of clay in a sand was tried on the Thunder Spring sand and no clay or fine particles were found. In the case of the Georgia river sands in which the property of singing was noted, very little clay or silt occurred in the sand. This is rather a peculiar circumstance. The sand from the Spring is composed mostly of irregular, angular, quartz grains, a very few grains of feldspar, and considerable mica in small flakes amounting to perhaps one per cent of the total. After most of the mica was removed the singing or crunching of the sand was less pronounced.

Chemical analysis of Thunder Spring sand, Upson County, T-103

Loss on ignition	0.18
Soda (Na_2O)	0.10
Potash (K_2O)	0.14
Lime (CaO	trace
Magnesia (MgO)	0.12
Alumina (Al_2O_3)	1.52
Ferric oxide (Fe_2O_3)	0.86
Manganous oxide (MnO)	t·ace
Titanium dioxide (TiO_2)	0.18
Silica (SiO_2)	96.75
Rare earths	0.00
Total	99.75

A sample of the sand after having remained in the laboratory for several months was found to still retain much of its original sonorousness. Quantities of water ranging from 1 to 10 per cent were added to the dried sand to see what influence moisture may have had, but little difference in the character of the sound was noted with the different amounts of water.

It is possible that in some cases this peculiar property of sand may be due to singularly clean and sharp grains rubbing together. Mica may add somewhat to the sonorousness of the sand.

APPENDIX D

MOLDING SAND TESTS

The results of detailed testing of ten Georgia molding sands made by the Bureau of Standards but received too late to be included in the body of the report are recorded here.

A summary of the tests, virtually the same as that submitted by the Bureau, is given, but only the leading features of the actual results are included for simplicity and economy of space.

Sieve tests.—The sieve tests showed the amount of sand retained on sieves Nos. 6, 8, 10, 14, 20, 30, 40, 50, 70, 100, 140, 200 and the amount passing No. 200, marked No. 200+, together with the average fineness of each sand.

Permeability tests.—These tests showed the permeability per cent of each sand by the use of an apparatus devised for the purpose, in use at the Bureau. The principle involved is that of ascertaining the amount of time it takes for an unlimited supply of air to pass through a given weight of sand rammed into a cylinder of metal, the ram falling through a height of two inches at each ram. The sand in every case is tempered and intimately mixed with 10 per cent of water. The time it takes for the air to pass through the given volume of sand is compared to the time it takes for the air to pass through the apparatus when the sand cylinder is empty. The result is expressed in terms of percentage of the time involved. The permeability of each sand is compared to the average permeability of the entire group of sands.

The shearing stress, bending moment, and ultimate fiber stress of the extreme fiber of the sand bar which is submitted by the weight of each bar or section of the same is calculated from the data derived from the test and the values obtained for each bar are compared to the average values obtained for the group. Tests were made on a bar of sand 12″ x 1″ x 1″ as a cantilever beam.

The melting point of each sand has been determined; determinations were made in an electric furnace and compared to the average melting point of the group. As all of the above sands are unknown in foundry practice there has also been added, for the sake of comparison, similar tests of the Standard Albany sand No. 2.

The following numbered sands, with their indicated locality, were tested:

No. 133, from bank of Coosa River opposite Nixon's Island near Rome, has an average fineness of 85.68 per cent with 61 per cent passing the 100-mesh sieve. It is the finest sand of the group as to grain size. Its permeability is below the average of the group. Its shearing stress and weight of bar is above, but its bending moment and ultimate fiber stress are below the average. Its melting point is below the average. As its permeability is about equal to that of Albany No. 2 it may be used as a brass molding sand.

No. 141, from bank of Coosa River, Neal's Ferry, has an average fineness of 82.91 per cent, which is above the average. Over 67 per cent of it passes the 100-mesh sieve. It ranks second in the fineness of its grains. Its permeability is far below the average, probably on account of its large per cent of clay substance. In fact, as to permeability it has the lowest value of the group. In weight of its bar, shearing stress and bending moment, it fell below, but exceeded the average in its ultimate fiber stress. This circumstance would indicate that the quality of its bond is unusually high. Its melting point is the lowest of the group, indicating that its clay substance is not very refractory, and even with this drawback it would make a good brass molding sand for small castings and fine-surfaced work.

No. 159, three miles southeast of Rossville, on the Central of Georgia Railway, fall below the average fineness, but still over 54 per cent of it passed the 100-mesh sieve, so that it cannot be regarded as a coarse sand. Its permeability is above the average, showing that its clay substance content is low. Its porousness is high because of the irregular size of its grains and their distribution. It possesses a peculiar pungent, agreeable odor which is not destroyed even at heating for several hours to 100° C. Its melting point is high, above the average, and would make a good molding sand for heavy iron work. In weight of the bar, and shearing stress it exceeded the average, but dropped below it in its bending moment and ultimate fiber stress. For large castings its molds would have to be well gaggered and chapleted.

No. 120, from the C. K. Gailey property, Almon, Georgia, has an average fineness of 80.75 per cent, far above the average. Over 54 per cent passed the 100-mesh sieve. Its permeability, however, is below the average on account of the fineness of its clay substance. Its porosity would be low. The weight of the bar and its shearing stress is above, but its bending moment and ultimate fiber stress are below the average, showing that its cohesive power is low. Its melting point is below the average, which would indicate that its clay substance is not refractory, but still it is good enough for brass molding sand.

No. 121, from the C. K. Gailey property, Almon, Georgia, is a mate to No. 120. In its sieve test it is below the average. Not quite 41 per cent passes the 100-mesh sieve. In permeability it is above the average and its porosity would be good. In shearing stress, weight of bar and bending moment, it is above the average, but in ultimate fiber stress it falls below. Its value is commensurate with that of No. 120. In its melting point it is the same as No. 120 and the same conclusions are to be drawn from this fact.

No. 165, from the property of Mrs. J. H. Smith, Ringgold, Georgia, in the sieve tests shows an average fineness of 82 per cent, considerably above the average. Over 65 per cent passes the 100-mesh sieve. In permeability it is below the average, which would indicate a high percentage of clay matter. Its optima water content would show that its porosity is also low. In shearing stress, weight of bar, and bending moment it is below the average, but by the ultimate fiber stress it is above the average, which would indicate that the quality of the bond is fairly good. In its melting point it is high, showing that the clay substance is highly satisfactory. It would make a good iron molding sand.

No. 162, from the Brockman property, Ringgold, Georgia, in the sieve tests shows an average fineness of 80.6 per cent, far above the average, with over 68 per cent passing the 100-mesh sieve. Its permeability is below the average, which would point to a large percentage of clay substance. In shearing stress, weight of bar, bending moment and ultimate fiber stress it is above the average. In melting point it is above the average but inferior to No. 165. It is a good all-round molding sand, and the indications are that it would be suitable as a body sand for every grade of iron molding requiring a strong sand, and would be suitable as a facing sand for light work.

No. 47, from the S. A. McBean property, one mile from McBean depot, in the sieve tests shows an average fineness much below the average, with not over 27 per cent passing the 100-mesh sieve. Its permeability as an off-set is far above the average, showing that it is devoid of the finer clay substance or silt that would clog its pores. Its optima water content would indicate a porous sand. Its shearing stress, weight of bar and ultimate fiber stress is below the average, but its bending moment is very high, which would indicate that its bond is above the normal value. Its melting point is high above the average, showing that its clay substance is highly refractory and also that its plasticity is high in quality because in quantity of the same it is low. From all indications it is the best brass or bronze or high melting point non-ferrous alloy molding sand in the group. It would also answer for all iron molding sand for small castings not requiring a fine surface.

No. 151, from Chattooga River, in the sieve tests shows an average fineness above the average of the group, as over 54 per cent of it passes the 100-mesh sieve. Its permeability is above the average, which would indicate that its clay substance is well distributed and that its porousness is good. Its shearing stress, weight of bar, bending moment and ultimate fiber stress are all above the average. Its melting point is high, which points to the fact that its clay substance is sufficiently refractory to permit of its being used as an iron molding sand of good quality for finely-surfaced iron castings. It is one of the best molding sands of the group.

No. 401, from Morse Brothers' pit, three miles south of Chattanooga, in the sieve tests shows an average fineness far below the general average, not over 31 per cent passing the 100-mesh sieve. Its permeability is considerably above the average, showing that it is an open sand. Its shearing stress, weight of bar, bending moment and ultimate fiber stress are above the average, and indicate a good bonding capacity. Its melting point is high, far above the average and is suitable for iron and mild steel casting work. It has the highest melting point of any sand in the group.

No. 2 Albany sand.—A standard brass molding sand is used as a basis of comparison with each number of the group. The sieve tests show it to be of greater average fineness than any sand in the group, as over 91 per cent of it passes the 100-mesh sieve. In its permeability it is somewhat above the average of the group, indicating that its clay substance is not excessive, and what is present is uniformly distributed. Its porosity is 33.8 per cent. In its shearing stress, weight of bar, bending moment and ultimate fiber stress it is below the average of the group; in fact, there are only three sands of the group that are inferior to it in this respect. In melting point, it is lower than that of any Georgia sand so far considered, and yet it is regarded as one of the best brass molding sands that have been used to any great extent in this country. An effort was made at the beginning to temper the various sands with water according to the optima content, but so many of them exceeded the limit of the water percentage they should take up for molding purposes that it was impossible to get their permeability records because of the excessive amount of clay contained in them, and therefore each of them was tempered and mixed with 10 per cent by weight of water or its equivalent.

TEST OF GEORGIA MOLDING SANDS

Number of sand	Sieve tests: Average fineness	Sieve tests: From 40 to 100 mesh inclusive	Sieve tests: Passing 100-mesh sieve	Melting Point, °C.	Permeability per cent: 1st ram	Permeability per cent: 2nd ram	Permeability per cent: 3rd ram	Shearing stress at point of support. Grams per sq. c. m.	Bending moments. Maximum at point of support. Grams per sq. c. m.	Ultimate fiber stress in extreme fibers of bar. Grams per sq. c. m.
133	85.68	36.34	61.47	1443	47.97	31.36	22.68	4.53	36.22	54.33
141	82.91	24.18	67.84	1392	26.55	18.88	15.00	3.88	43.78	65.63
159	67.83	56.44	34.18	1535	75.36	51.66	44.75	4.64	37.48	55.65
120	80.75	41.55	54.53	1395	65.74	43.33	35.89	4.82	22.42	57.80
121	73.00	50.84	40.98	1395	65.99	42.70	31.06	4.48	50.59	54.92
165	82.06	29.65	65.45	1580	36.45	23.63	18.60	4.02	45.15	67.67
162	80.62	22.15	68.13	1555	31.37	21.36	16.07	4.42	50.43	67.76
47	58.91	63.41	24.46	1575	75.56	53.20	42.70	3.76	68.39	34.02
151	79.53	39.94	54.48	1564	60.98	37.47	27.62	4.65	52.89	79.25
401	58.05	54.17	30.95	1600	79.54	52.55	35.81	4.58	58.61	84.83
Average	74.93	41.867	50.247	1371	43.16	35.64	32.81	4.38	46.60	62.19
Albany No. 2	96.90	9.51	91.34	1503	56.55	37.61	29.02	4.31	19.41	38.83

INDEX