Common Clays Of The Coastal Plain Of South Carolina

And Their Use In Structural Clay Products

By

G. C. ROBINSON, B. F. BUIE, and H. S. JOHNSON, Jr.

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TO THE HONORABLE ERNEST F. HOLLINGS
GOVERNOR OF SOUTH CAROLINA

Sir:

Submitted herewith is State Development Board Bulletin 25, *Common Clays of the Coastal Plain of South Carolina.* This report by Robinson, Buie, and Johnson was prepared as part of the Division of Geology's continuing program of investigations of the geology and mineral resources of the State.

Abundant resources of common clays in the Coastal Plain are found to be suitable for making brick and a wide variety of other structural clay products, including lightweight aggregate.

Sincerely,

W. W. HARPER, *Director.*

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BY
G. C. ROBINSON, B. F. BUIE, AND H. S. JOHNSON, JR.

ABSTRACT

Annual production of the American structural clay products industry is currently valued at about $375,000,000. Rapid technological advances are being made in this industry, and increasingly stringent requirements are being placed on the raw materials used.

Clay resources of the South Carolina Coastal Plain include kaolin clays, siliceous shale or "fullers earth", bentonite, and common clays. Commercial kaolin deposits occur in the Tuscaloosa formation of Upper Cretaceous age in the northwestern part of the Coastal Plain. Siliceous shale, or "fullers earth" as it has been called, is present in beds of Eocene age in Aiken, Lexington, Calhoun, Sumter, Williamsburg, and Georgetown Counties. Non-swelling bentonite occurs over hundreds and possibly thousands of acres in Jasper County. Common brick clays are present at a great many places throughout the Coastal Plain.

Laboratory investigations of 42 samples of clays indicate that resources of common clays suitable for use in structural clay products are abundant in the Coastal Plain of South Carolina. Some clays are well suited for almost the whole range of structural clay products. Others would require selective mining and blending of materials to overcome defects.

Investigations of the effect of the sand content of a clay on its ceramic properties indicate that a greater amount of sand in the minus 48 plus 100 mesh size range can be tolerated than can coarser or finer sand. Removal of sand by washing greatly increases the dry and fired strengths of clays and commonly results in a lower maturing temperature, reduced absorption, and smoother surfaces after firing.

INTRODUCTION

The manufacture of structural clay products constitutes an important part of American industry with an annual production currently valued at about $375,000,000. Somewhat belatedly the structural clay products industry has in recent years been undergoing a transformation to a truly modern industry from what had in the past been more in the nature of a craft. Great changes have already taken place, and further rapid technological advances are expected in the years to come.

Mechanization of the structural clay products industry is placing increasingly stringent requirements on raw materials, and frequently the properties of the raw material determine whether or not an additional step in mechanization is feasible. The pursuit of lower manufacturing costs and better products through technological advances has focussed attention on the properties of raw materials and has stimulated a search for those which are more amenable to modern manufacturing procedures. Better raw materials are also needed to improve product quality in order to maintain the competitive position of structural clay products relative to other building materials.

Clay resources of the South Carolina Coastal Plain include kaolin clays, siliceous shale or "fullers earth", bentonite, and common clays (Plate 1). Table 1 gives a brief description of the geological formations in which these materials occur.

The sedimentary kaolins of South Carolina and Georgia occur as lenses as much as a mile in length and up to 50 feet in thickness in the Tuscaloosa formation (Table 1) of Upper Cretaceous age. They are widely distributed throughout the outcrop area of the Tuscaloosa formation in a northeast-trending belt at the northwestern margin of the Coastal Plain. In South Carolina the higher grade kaolin deposits are principally in Aiken County, and production of kaolin from this district is currently valued at about $6,000,000 annually. The deposits have been described by many authors, particularly Kesler (1956); and the properties and uses of the kaolin clays have been well covered in a book on *Kaolin Clays and Their Industrial Uses*, published by the J. M. Huber Corporation in 1955. The principal uses of kaolin are in the paper, rubber, refractories, pottery, adhesives, cement, insecticide, linoleum and oilcloth, and paint industries.

Siliceous shale, or "fullers earth" as it has been called, is present in beds of Eocene age in Aiken, Lexington, Calhoun,

Table 1.—Description of geologic formations in the South Carolina Coastal Plain and their correlation with Gulf Coast and Middle Atlantic Coast equivalents [1]

System	Series	Group	Gulf Coast	South Carolina	Middle Atlantic Coast	Description of formation in South Carolina
Quaternary	Recent					Light-gray and tan fine to coarse lenticular sand and interbedded clay of marine and continental origin.
	Pleistocene		Beaumont clay Lissie formation	Pamlico Talbot Penholoway Wicomico Sunderland Coharie Deposits of Hazlehurst terrace	Pamlico Talbot Penholoway Wicomico Sunderland Coharie Deposits of Hazlehurst terrace	Light-gray, tan, orange, red, and black clay interbedded with sand and gravel. Deposits form a thin cover over greater portion of Coastal Plain.
Tertiary	Pliocene		Willis (Pliocene?) sand Goliad sand	Waccamaw fm.	Brandywine fm. (Pliocene?) Waccamaw fm.	Blue-gray to yellow and brown sandy shell marl.
	Miocene		Lagarto (Miocene?) clay	Duplin marl	Yorktown fm.	Buff sandy, friable shell marl occurring in isolated patches in lower half of Coastal Plain.
			Oakville ss.	Hawthorne fm.	St. Marys fm. Choptank fm. Calvert fm.	Hard, brittle shale resembling silicified fuller's earth, with fine sandy phosphatic marl.
			Catahoula ss.	? Tampa(?) limestone*		White sandy phosphatic, fossiliferous limestone with molds and fragments of macrofossils.
	Oligocene		Vicksburg or Upper Suwanee ls.	Flint River fm.	?	Broken lumps of yellow vitreous chert in reddish-yellow sand. Chert is sparingly fossiliferous.
			Red Bluff clay	Cooper marl**	?	Light-brown to grayish-green marl, phosphatic.
	Eocene	Jackson	Jackson group	Barnwell fm.	Piney Point fm.	The Barnwell consists typically of deep-red to brown fine to coarse massive sandy clay and clayey sand. It appears to represent a residuum derived from solution of a sandy limestone.
		Claiborne: Upper	Cockfield or Gosport sand	Castle Hayne limestone		Buff-gray tough or crumbly fossiliferous limestone underlain by soft fine-grained granular limestone. Fore reef deposit.
		Claiborne: Middle	Cook Mountain fm.	McBean fm. / Santee limestone	Nanjemoy fm.	The McBean formation consists of fine- to medium-grained massive greenish-yellow and red quartz sand, green glauconitic marl, silicified beds of coquina, and clayey sand interbedded with red, brown, ochre, and yellow clay laminae. Littoral to neritic environment gradational with some estuarine or continental. The Santee limestone is a nearly pure white to creamy-yellow fossiliferous and partly glauconitic limestone containing numerous Bryozoa. Fore-reef deposit.
			Zilpha clay Winona sand	Warley Hill marl		Fine green to yellow glauconitic sand overlain by yellow to reddish-yellow sandy clay.
		Claiborne: Lower	Tallahatta fm.	Congaree fm.		Well to poorly sorted sand, fuller's earth, brittle siltstone, and light-gray to green shale alternating with thin-bedded fine-grained sandstone.
		Wilcox	Hatchetigbee to Nanafalia fm.	Black Mingo fm.	Aquia fm.	Partly indurated fine white to yellow sand and sugary sandstone or bioclastic limestone. Cement is white and calcareous to siliceous. Underlain by gray to black laminated shales containing numerous macrofossils in some areas.
	Paleocene		Wills Point Kincaid fms.	Unnamed—may be in part Black Mingo	Brightseat fm.	Black to gray laminated clay interbedded with fine white sand and in some areas containing many shells.
Cretaceous	Upper Cretaceous	Navarro	Kemp clay to Neylandville marl	Peedee fm.	Monmouth fm.	Dark-green to gray micaceous, glauconitic, argillaceous sand interbedded with impure limestones and massive dark clays. Deposited under open marine conditions probably at depths of not less than 100 fathoms.
		Taylor	Taylor group	Black Creek: Snow Hill marl member	Matawan group	Light-gray sand and dark clays interbedded with green sand and marine clay. Transitional zone between the deeper marine Peedee formation and the more shallow marine Black Creek deposits.
		Austin	Austin chalk	Black Creek: Unnamed member	Magothy fm.	Dark-gray to black laminated lignitic clays interbedded with white to gray phosphatic, glauconitic sand. Deposited in shallow marine, estuarine, and paludal environment.
		— — —	Eagle Ford shale	Deposits of Eagle Ford age*		Gray, buff, and red arkosic cross-bedded sand and gravel, interbedded with lenses of white and purple clay and kaolin. Mixed continental and marine environment characterized by fluvial, deltaic, and littoral deposits.
		Woodbine	Woodbine sand	Tuscaloosa fm.	Raritan fm.	

*Recognized only in the subsurface.

**The U. S. Geological Survey has not recognized the Cooper as including material of Eocene age in South Carolina. However, material of Eocene age has been recognized in the Cooper in wells drilled in the Savannah area, Georgia, just across the Savannah River from southeasternmost South Carolina. The writer believes that such material may exist in South Carolina also.

[1] After Siple, 1959.

Sumter, Williamsburg, and Georgetown Counties. Where exposed at the surface this material is a buff colored, highly porous, shale-like clay that is composed of about 80 percent silica, much of which is in the form of cristobalite. The siliceous shale has a very low dry strength and has yet to be used to any great extent in the structural clay products industry. Its porosity and high absorptiveness, however, make it potentially useful for oil clarification, filler, binder, insecticide diluents, and other similar purposes.

A unique deposit of non-swelling bentonite occurs in Jasper County, S. C. This deposit is up to 20 feet in thickness and extends over hundreds and possibly thousands of acres. It is potentially useful for a variety of industrial purposes such as well drilling mud, foundry bonding clay, oil clarification, filler, binder, plasticizer, and as a raw material for the production of lightweight aggregate.

Common clays are present in great abundance in the South Carolina Coastal Plain and are the basis for an ever growing structural clay products industry. The principal purpose of this report is to present information on the occurrence, ceramic properties, and uses of these clays. Field investigations and sampling of representative clays were carried out principally by B. F. Buie and to a lesser extent by H. S. Johnson, Jr., both with the Division of Geology, S. C. State Development Board. Laboratory investigations were conducted by G. C. Robinson, Head, Ceramic Engineering Department, Clemson College. The work was done as part of the State Development Board's program of appraising and furthering the development of the mineral resources of the State.

OCCURRENCE AND DISTRIBUTION OF COMMON CLAYS

There is no standard definition of the term "clay", but it is generally understood to be a natural, earthy, fine-grained material which exhibits plasticity when wet. Plasticity is one of the most important properties of clay since it permits molding of clays into almost any desired shape. Plasticity may be defined as the property of being amenable to permanent deformation without fracture. Clays range in plasticity from highly plastic clays, sometimes called "fat" or "rich", to those of low plasticity, called "lean" clays. The variation in plasticity from one clay to another may be caused by changes in particle size, the type of clay mineral present, soluble salts and absorbed ions, organic matter, and the amount and type of non-clay minerals present. The amount and particle size distribution of the non-clay minerals is a particularly significant cause of variation in plasticity of impure clays.

There are several systems of naming clay types and each one has its own particular merits. The clays of primary concern to this investigation are impure clays that contain major quantities of non-clay minerals and significant quantities of iron. These clays are termed "common clays" in this report.

Common clays are present in one form or another at or within a few feet of the surface over much of the Coastal Plain of South Carolina. For the most part these clays are of too limited extent or are too inhomogeneous or otherwise too poor in quality to justify commercial development. At some places, however, there are very large, uniform deposits of clays which are well suited as raw materials for one or more structural clay products.

In general, common clays of the South Carolina Coastal Plain can be classified in one of three categories—bedded clays of Cretaceous and Tertiary age, generally inhomogeneous marine deposits of probable Pleistocene age, and younger alluvial and estuarine clays.

BEDDED CRETACEOUS AND TERTIARY CLAYS

Bedded common clays of Upper Cretaceous and Tertiary age are known within a few feet of the surface as well as at greater depths at many places in the Coastal Plain of South Carolina. Clays of the Black Creek and Pee Dee formations (Upper Cretaceous) (Table 1) are commonly dark colored and interbedded with sand and are thought to be of marine origin. Black to green, bentonite clays of Eocene age and bluish-gray to black, plastic clays of Miocene or Pliocene age have been found at a number of places.

Bedded Cretaceous and Tertiary clays are rarely well exposed and usually are recognized only in artificial exposures or in drill holes. Clays of this sort have been encountered in Division of Geology drill holes Georgetown No. 2 through No. 5, Williamsburg No. 1 through No. 4, Williamsburg No. 6, Calhoun No. 4, Calhoun No. 7, Sumter No. 1 through No. 5, Orangeburg No. 9, and Orangeburg No. 25 (Plate 1). Natural and artificial exposures of bedded Tertiary clays are fairly abundant in the vicinity of Creston and St. Matthews in Calhoun County and near North and Livingston in Orangeburg County.

Bedded common clays of Cretaceous and Tertiary age have not been developed commercially as yet in South Carolina, but they are thought to have considerable potential for use in the structural clay products industry. At many places where these clays have been encountered in drill holes, the clay bed has been at too great a depth below the surface to be mined economically. Where it is established that a clay is suitable for industrial purposes, however, the clay bed in question can often be traced to a point of surface outcrop or to an area where it is covered by only a few feet of overburden.

PLEISTOCENE (?) MARINE CLAYS

Sandy clays of probable marine origin are widespread at or within a few feet of the surface over much of the lower Coastal Plain of South Carolina, principally at elevations below 100 feet. These deposits were for the most part laid down in shallow, nearshore waters during periods of higher sea level in Pleistocene time. The clays are characteristically mottled red-orange-yellow-brown-white sandy clays, but they may be cream colored to brown and relatively free from sand in places. The clay fraction of these deposits is commonly very plastic so that the material holds together well, even when quite sandy.

Investigations on Medway Plantation in Berkeley County, S. C. (Robinson and Johnson, 1960, p. 9) indicated that deposits of these Pleistocene (?) marine clays—called "Spring Grove type" on Medway—may be up to 12 feet and possibly more in thickness but that they can be expected to interfinger and grade both vertically and laterally into deposits of fine-grained sand and consequently may be irregular and unpredictable in outline. Successful utilization of these clays will probably require selective mining and blending to obtain the material most suited to the product desired.

ALLUVIAL AND ESTUARINE CLAYS

Extensive, relatively homogeneous clay deposits occur in floodplain and terrace deposits of many large Coastal Plain creeks and rivers. The deposits range from silty and sandy clay to rich, plastic clay. In the lower Coastal Plain some of these deposits overlie marl and grade downward into it (Robinson and

Johnson, 1960, p. 9) and appear to be estuarine deposits that have been formed largely from weathered and reworked marl. The younger alluvial and estuarine clays differ from the Pleistocene (?) marine clays described above in being relatively less sandy and in being relatively more uniform throughout the deposit.

STRUCTURAL CLAY PRODUCTS

Structural clay products is a broad category that includes brick, roofing tile, quarry tile, drain tile, sewer pipe, paving brick, glazed tile, and other similar items. Desirable properties vary among the different products, but fireproofness and durability are common to them all. The manufacturing process of all the products necessitates pretesting for fire resistance in that they are all fired in kilns at temperatures between 1800° and 2400°F. Any tendency towards combustion would eliminate the product during this test. The durability of structural clay units has placed them above many other materials in that they do not rust or disintegrate with age, nor are they attacked by termites, other vermin, or most chemicals.

Appearance, absorption, hardness, strength, and resistance to abrasion are properties that are important in determining the usefulness of structural clay products. In addition to the requisite properties specified for a particular product, the manufacturing process places certain distinct demands on the properties of the raw material used. In general, such properties as plasticity, dry strength, drying and firing shrinkage, and firing range determine whether or not the clay can be manufactured into structural products efficiently and economically.

The molding of structural clay products is usually accomplished by the process of extrusion. The plasticity of a clay determines to a large measure the ease with which the clay can be shaped into the desired product by extrusion. The plasticity also indicates whether or not the formed object will have sufficient strength to withstand the necessary handling between the extruder and the dryer. The moldability and the plastic strength of a clay can be evaluated by a test of its extrusion strength.

The manufacture of structural clay products requires that the shaped object have sufficient strength when dry to permit handling and stacking on kiln cars. The dry strength of a clay indicates how well it can withstand handling and stacking in the dry condition. Dry strength frequently parallels the plasticity of clays, the more plastic clays usually showing high dry strengths. Increasing quantities of non-clay minerals reduce the plasticity and the dry strength of impure clays except that in some instances increasing amounts of non-plastics reduce or eliminate cracking during drying and thus give an improvement in dry strength.

Drying and firing shrinkage are important properties of structural products raw materials. The greater the sum of these shrinkages, the more difficult it is to make products to close dimensional tolerances. Increasing magnitude of drying shrinkage also indicates increasing danger of cracking or warping during drying. Very plastic or "fat" clays commonly have a high drying shrinkage while sandy or "lean" clays have a low drying shrinkage.

The firing process develops the desired product properties as it changes the clay into a hard, strong material. Some clays will develop suitable properties at relatively low temperatures and thus permit production with low consumption of fuel. Other clays may be refractory in nature and require very high maturing temperatures with much greater fuel consumptions. Many clays develop desirable properties over a range of temperatures (firing range) rather than at a single temperature. Clays with a long firing range are desirable while clays with a short firing range are difficult to fire properly.

BUILDING BRICK

The specifications normally placed on brick are concerned with the strength, absorption, saturation coefficient, and dimensional tolerance of the unit. A good quality building brick should have a minimum modulus of rupture of 600 pounds per square inch or a minimum compressive strength of 3,000 pounds per square inch.

The resistance of brick to freezing and thawing weather can be conclusively determined by actually submitting the brick to alternate freezing and thawing cycles. The performance of such a test is so lengthy and arduous that it is not practical as a routine control measure, and consequently simpler tests have been sought to give an indication of the brick's resistance to freezing and thawing. The total absorption has at times been used as such a test and is often used in brick specification. However, it has been shown that there is no correlation between total absorption values and resistance to freezing and thawing. A better test is the determination of the saturation coefficient (C/B ratio), which is the ratio of absorption after 24 hour submersion in cold water to that after 5 hour submersion in boiling water. This gives the ratio of easily accessible pores to total pores, and the lower it is the better the resistance of the brick supposedly is to freezing and thawing. Brick with low total absorption (less than 8 percent by weight after submersion in boiling water) may show a high C/B ratio and yet have a good resistance to freezing and thawing. In this event, the requirement for C/B ratio is usually waived.

The permissible absorption and C/B ratio vary with the severity of weather conditions which the brick must face. Brick intended for use where they will be subject to freezing temperatures while saturated with moisture should have an absorption of less than 17 percent and a C/B ratio of less than 0.78. Higher absorptions and C/B ratios are permitted for less severe conditions, and there is no limit when the brick are intended for back-up or interior masonry.

The rate of absorption is a useful property although it is seldom specified or required. This property gives an indication of how well brick will take mortar. It indicates whether the brick will suck up water too rapidly, thus weakening the mortar, or whether the brick is so impervious that it will bond poorly with the mortar. The optimum rate of absorption is 20 grams for the first minute when the flat side of a brick is immersed to a depth of 1/8″ in water. Brick of higher rates of absorption can be wetted with water prior to laying, thus effectively reducing the rate of absorption. Test bricks should be made to within ± 3 percent of the specified dimension.

The manufacturing process places requirements on brick clays in addition to those specified for the manufactured product. The clay should possess sufficient plasticity to permit molding into brick. The extrusion strength of the clay is a measure of this plasticity, and a minimum extrusion strength of 3 inches is specified for brick clays that are to be fabricated by stiff mud machinery.

The dry strength of a clay gives additional information on plasticity and also determines whether or not units formed from it will be strong enough to permit the necessary handling prior to firing. The dry transverse strength should exceed a modulus of rupture of 70 pounds per square inch.

The total linear shrinkage of a brick clay should be less than 16 percent, and the clay should dry without cracking or warping.

Table 2.—Range in physical properties of some Ohio brick clays.

Dry tranverse strength	160-573 lbs. per sq. inch
Fired tranverse strength	1291-5039 lbs. per sq. inch
Drying shrinkage	1.5-4.3% linear
Firing shrinkage	0.7-10.3% linear
Firing range	160-369° F.

Table 2 gives the range of properties of some of the clays and shales currently being used in the manufacture of brick in Ohio. Table 3 gives the range of properties of South Carolina clays and shales used in brick manufacture.

Table 3.—Range in physical properties of South Carolina materials used in brick manufacture.

Dry tranverse strength	125-986 lbs. per sq. inch
Fired tranverse strength	872-2720 lbs. per sq. inch
Drying shrinkage	3.1-6.8% linear
Total shrinkage	2.8-11.7% linear
Firing range	100-350° F.
Maturing temperature	2000-2350° F.

FACE BRICK

The function of face brick is primarily to provide an attractive appearance in a brick wall. Frequently face brick are sold on the basis of appearance only, with no regard for the physical properties of the brick. The best face brick is the brick with the most attractive appearance, no matter whether it be soft, porous, warped, cracked, misshapen, or overfired. The only requirement placed on a clay for it to be suitable as a raw material for this type of face brick is that the clay make an attractive brick.

In special cases, or in some other sections of the country, the term face brick sometimes connotes a brick with superior physical properties, particularly in regard to uniformity of size, freedom from cracking or warping, high strength, and low absorption. A good grade of common brick clay is required for this product.

HOLLOW TILE

Strength and absorption are important properties of hollow tile. Specifications vary with the many applications of this product, but most tile fit into one of three specification groups—load-bearing tile, non-load-bearing tile, and floor tile.

Strength specifications for load-bearing tile generally require a clay with a minimum fired modulus of rupture of 1500 lbs. per sq. inch. Clays for the manufacture of floor tile should have a fired modulus of rupture greater than 2000 lbs. per sq. inch.

In general, hollow tile products have a permissible absorption range of from 5 to 25 percent. However, load-bearing tile that are to be exposed to the weather have a permissible absorption range of 5 to 16 percent.

To be suitable for the manufacture of hollow tile, clay should have good plasticity and good extrusion qualities. The extrusion strength should be in excess of 4 inches, and the dry modulus of rupture should exceed 180 lbs. per sq. inch. The comparatively thin walls of hollow tile permit the use of a clay with poorer drying properties than can be tolerated in the manufacture of common brick. In no case, however, should the clay crack or warp upon drying or firing. Table 4 gives the range of physical properties of clays currently used in the manufacture of hollow tile in Ohio.

Table 4.—Range in physical properties of Ohio hollow tile clays.

Dry tranverse strength	281-475 lbs. per sq. inch
Fired tranverse strength	1338-4243 lbs. per sq. inch
Firing range	297-369° F.
Extrusion strength	2.7-7.7 inches
Drying shrinkage	2.0-5.4% linear
Firing shrinkage	0.13-7.5% linear

DRAIN TILE

Specifications for drain tile are concerned chiefly with the ability of the product to support loads and with the resistance to freezing temperatures. Load-bearing qualities are generally satisfactory if the tile has a fired modulus of rupture in excess of 1200 lbs. per sq. inch. Resistance to freezing temperatures in the presence of moisture can be determined by subjecting a tile to alternate freezing and thawing cycles or by determining the saturation coefficient. Absorption is also an indication of this resistance, and it is customary to specify the maximum absorption permissible in tile. Commonly such specifications allow a maximum absorption of 14 percent, but some drain tile have absorptions as high as 16 percent. The normal range in absorption is between 7 and 16 percent for most drain tile.

Clay for the manufacture of drain tile must have properties similar to those of a hollow tile clay. The maximum permissible total linear shrinkage is 16 percent for drain tile clay. The range of physical properties of some Ohio clays used in the manufacture of drain tile are shown in Table 5.

Table 5.—Range in physical properties of Ohio drain tile clays.

Dry transverse strength	281-945 lbs. per sq. inch
Fired transverse strength	1338-3505 lbs. per sq. inch
Firing range	297-369° F.
Extrusion strength	3.2-12.9 inches
Drying shrinkage	2.0-7.1% linear
Firing shrinkage	0.02-8.0% linear

SEWER PIPE

Specifications for sewer pipe are more stringent and varied than those applied to brick. Particular attention is paid to absorption, strength, flaws, and the finish of the pipe.

Fired absorption for sewer pipe should be 8 percent or less.

Strength is usually specified as the crushing strength of the pipe expressed in pounds per linear foot. Although there is no direct correlation between the transverse strength of fired test bars and the actual strength of the ware, clays which have a fired modulus of rupture of more than 2000 lbs. per sq. inch will usually make a pipe of satisfactory strength.

Sewer pipe usually has a salt glaze finish. This may restrict suitable clay deposits because many clays are not receptive to salt glazing. The amenability of a particular clay towards salt glazing must be determined by glazing tests on a representative sample of the clay.

Sewer pipe are required to be free from warping and any structural defects which would be detrimental to the strength or water imperviousness of the pipe.

Clay of very high quality is required for sewer pipe, and such clay is much more restricted in occurrence than are clays suitable for the manufacture of brick or hollow tile. The manufacturing process, the intricacies of shape, and the large size of some of the units place additional limitations on sewer pipe clays. The clay should be highly plastic and tough and must have good drying properties. Dry strength should be high, with a minimum dry modulus of rupture of 200 lbs. per sq. inch. The vitrification range of the clay must be long, with only a small amount of shrinkage allowable during vitrification. Because of the strict requirements for the raw material, it is common to use blends of clays in sewer pipe manufacture rather than to rely on clay from a single deposit.

Table 6.—Range in physical properties of Ohio sewer pipe clays.

Dry transverse strength	290-345 lbs. per sq. inch
Fired transverse strength	2579-4171 lbs. per sq. inch
Vitrification range	140-396° F.
Drying shrinkage	2.6-3.9% linear
Firing shrinkage	2.1-7.8% linear
Extrusion strength	4-12 inches

Table 6 shows the range in physical properties of some of the clays and shales used in the manufacture of sewer pipe in Ohio. Firing properties of a South Carolina clay once used in sewer pipe manufacture are given in Figure 7.

PAVING BRICK

Paving brick must be very strong, tough, and dense. The internal structure of the product should have the appearance of a dense, stony mass that is free from laminated structure or inclusions of nodules or bubbles. Bulk density of the brick should be greater than 2.3 grams per cubic centimeter, and the absorption should be less than 8 percent. The absorption of paving brick is sometimes specified to average 2 percent with an individual maximum of 3 percent. The fired modulus of rupture of paving brick should exceed 2000 lbs. per sq. inch, and good brick commonly average over 2700 lbs. per sq. inch.

Paving brick clays must have properties distinct from other clays in order to meet the requirements given above. Table 7 gives the range in physical properties of some clays used for the manufacture of paving brick in Ohio.

Table 7.—Range in physical properties of Ohio paving brick clays.

Dry tranverse strength	193-470 lbs. per sq. inch
Fired transverse strength	3137-3714 lbs. per sq. inch
Drying shrinkage	2.1-2.8% linear
Firing shrinkage	6.3-8.6% linear
Extrusion strength	2-4 inches
Firing range	63-180°F. (0-4% absorption)

QUARRY TILE

Quarry tile must be strong, dense, vitreous, tough, and resistant to abrasion. It must have an absorption of 6 percent or less, and the fired modulus of rupture should be in excess of 2700 lbs. per sq. inch. Clay for the production of quarry tile should have a good plasticity and a dry strength greater than 180 lbs. per sq. inch. No warping can be tolerated during drying or firing.

ROOFING TILE

To meet specifications for roofing tile, clay should have a dry modulus of rupture in excess of 125 lbs. per sq. inch. It must dry and fire without warping and should have a low and gradual firing shrinkage to permit production of units of uniform size. Fired absorption should exceed 4 percent in order to prevent sweating on the underside of the tile. Maximum permissible absorption varies a great deal, but a good tile should be fired to have less than 12 percent absorption. Roofing tile should have a fired modulus of rupture of over 1500 lbs. per sq. inch and preferably over 2500 lbs. per sq. inch.

POTTERY

Pottery products include earthenware, stoneware, crockery, and glazed ware. Properties of the product and the raw material are subject to wide variations, but the better grade products are usually made from dense-burning semirefractory clays. It is not necessary that the clays be white burning.

The designation of a clay as pottery clay depends largely on the taste of the potter who plans to use it. He needs material which will work well in his particular manufacturing process and usually wants a clay of high plasticity and low firing temperature. High dry strength and retention of form while burning are very desirable, and a fine-textured clay is preferred.

LIGHTWEIGHT AGGREGATE

Lightweight concrete aggregate produced from clay, shale, or slate is being used in ever-increasing amounts in construction where a saving in weight without serious loss of strength is desired. Concrete made with sand, gravel, or crushed rock weighs 145 to 150 lbs. per cu. ft. compared with 50 to 90 lbs. per cu. ft. for concrete made with the lightweight product.

Clays suitable for the manufacture of lightweight aggregate must bloat and expand when heated rapidly to the range between incipient and complete fusion. The bloating or vesiculation requires the presence of substances that release gas after the clay has been heated sufficiently to make it pyroplastic. It is also necessary that the permeability of the firing clay be sufficiently low to trap the gas within the clay. Under these circumstances, the expanding gases cause the clay or shale to expand much as gas formation causes bread to rise. The type of clay mineral, the type and amount of non-clay matter, and the quantity of alkalies and alkaline earths all influence the bloating qualities of a clay. The gas causing bloating is subject to some debate but probably is an oxide of carbon or sulphur or a combination of these gases. In some cases clays which do not bloat sufficiently upon firing can be enriched by additions of bentonite, marl, fly ash, fuel oil, coal dust, or the like. Additions of fluxes such as lime are sometimes required to lower bloating temperatures, and additions of more refractory clays are sometimes needed to extend the bloating range and prevent premature melting and slagging down.

LABORATORY TESTING PROCEDURE

The laboratory procedure used in this investigation was modified from procedures described on pages 334-530 in Volume 11, No. 6 of the Journal of the American Ceramic Society. Properties determined include dry strength, extrusion strength, drying shrinkage, dry bulk density, apparent porosity, water of plasticity, fired strength, and fired properties for various firing temperatures. These properties indicate whether or not the clay can be fabricated by conventional manufacturing processes and whether or not the clay is capable of producing the requisite properties in the finished product.

Only one specimen was used in the determination of water of plasticity and drying shrinkage, and one draw trial was made for each test temperature.

Strength determinations were made on ten specimens in accordance with standard procedure. The specimens for fired strength were fired to a temperature near the upper end of the maturing range for the particular clay sample.

Drying characteristics were evaluated by introducing a wet 1½" x 1½" x 3" brick directly into an air circulating dryer operating at 300° F. The effect of this on the specimen gave an indication of the ability of the clay sample to withstand rapid drying. A similar test brick was dried at 150° F for 4 hours and then for an additional 8 hours at 220° F. The effect on this specimen indicated the clay's performance on slow drying schedules.

PROPERTIES OF COMMERCIALLY ACCEPTED RAW MATERIALS

Figures 1 through 10 show the firing characteristics of materials actually being used in the manufacture of structural clay products. The firing characteristics of these accepted materials were determined in the same manner as those of the clays sampled and studied in the course of this investigation. They thus provide a basis for comparison between known and unknown. The data used in making Figures 8, 9, and 10 were obtained from the report, *Surface Clays and Shales of Ohio,* prepared by Chester R. Austin and published by the Ohio State University.

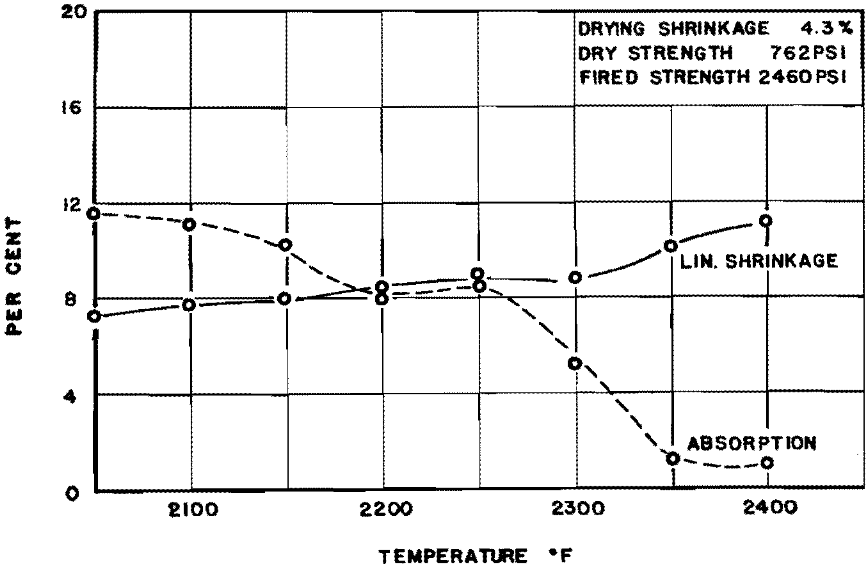

FIG. 1—FIRING RANGE OF CLAY FROM PALMETTO BRICK WORKS, MARLBORO COUNTY, S. C.

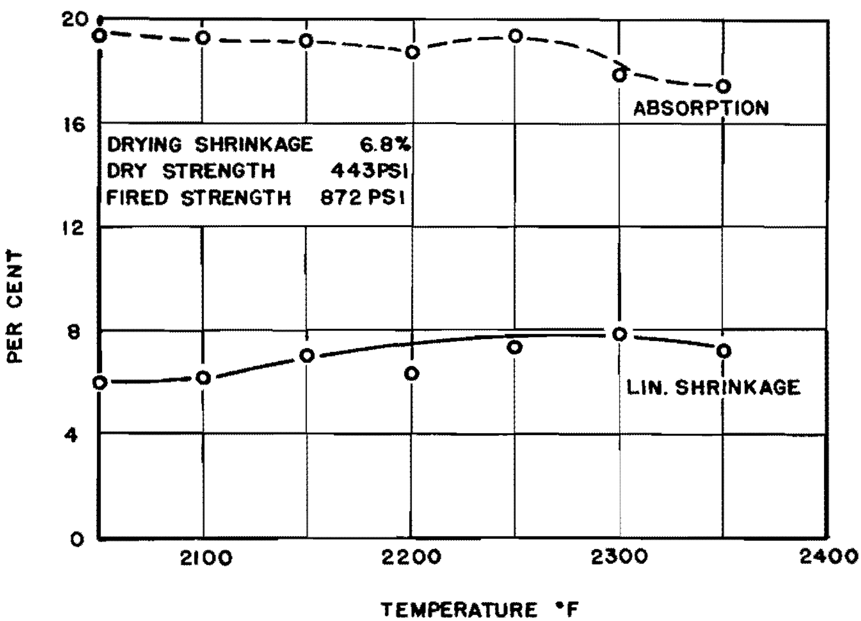

FIG. 2—FIRING RANGE OF CLAY FROM SUMMERVILLE BRICK WORKS, DORCHESTER COUNTY, S. C.

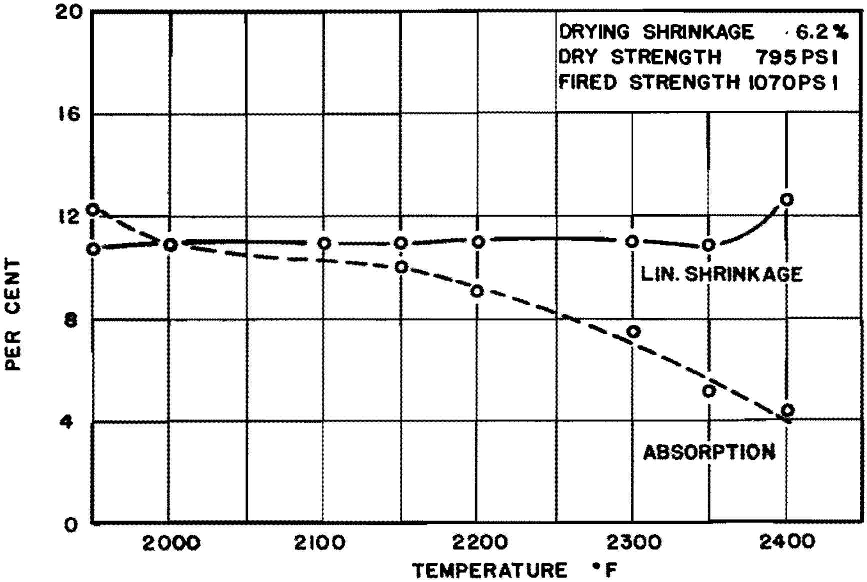

FIG. 3—FIRING RANGE OF CLAY FROM CONSUMERS BRICK YARD, SOCIETY HILL, S. C.

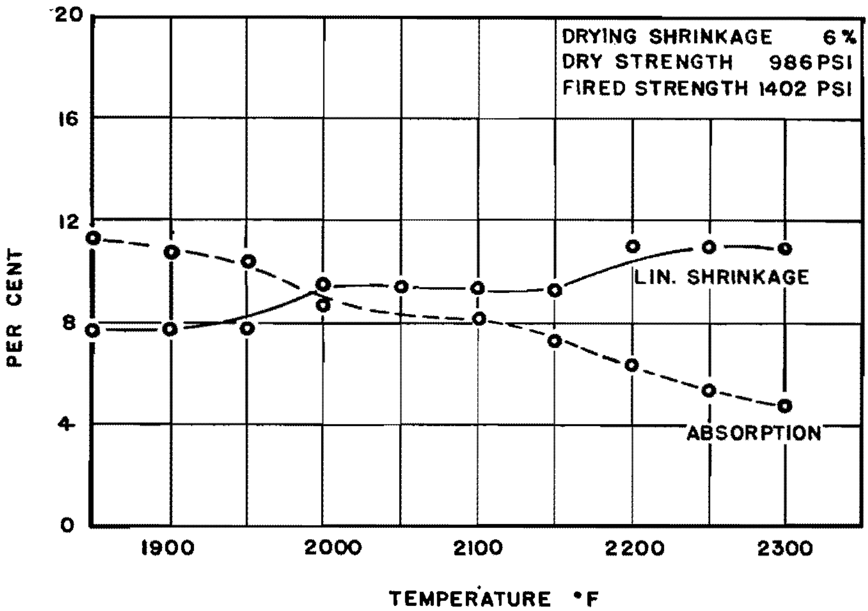

FIG. 4—FIRING RANGE OF CLAY FROM CHERAW BRICK WORKS, MARLBORO COUNTY, S. C.

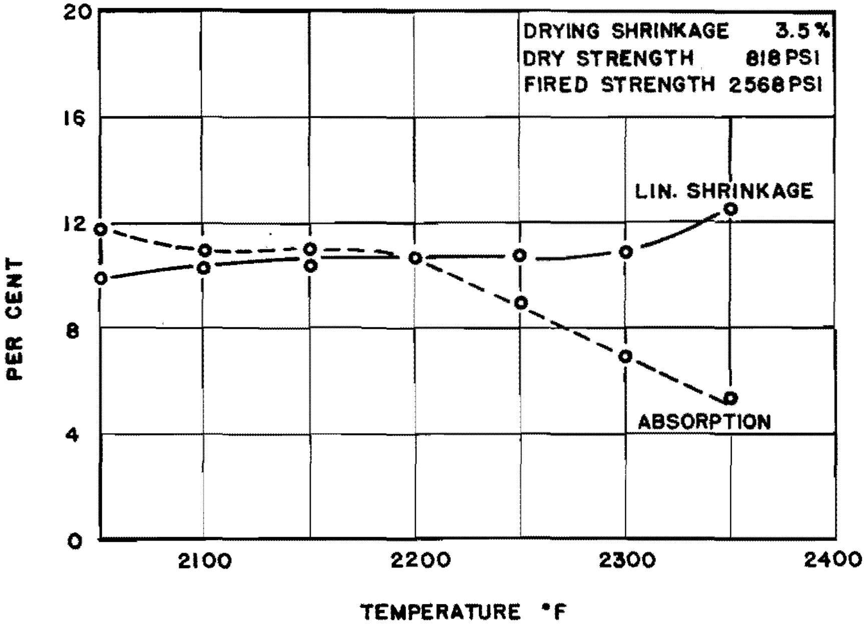

FIG. 5—FIRING RANGE OF CLAY FROM BLUE BRICK WORKS, MARION COUNTY, S. C.

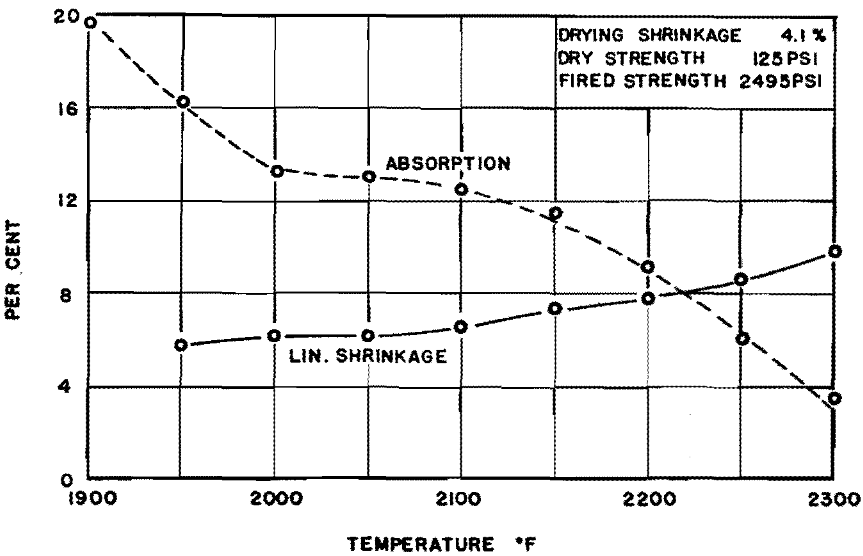

FIG. 6—FIRING RANGE OF CLAY FROM RICHLAND SHALE PRODUCTS COMPANY, RICHLAND COUNTY, S. C.

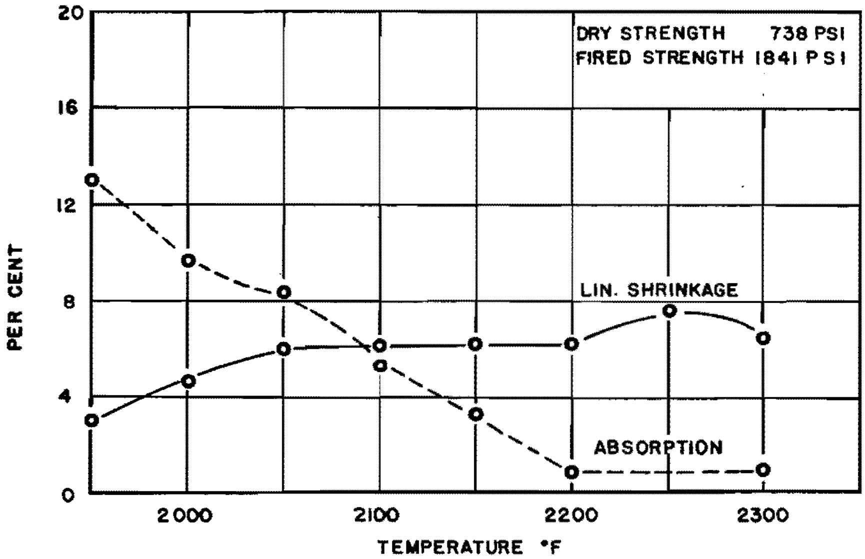

FIG. 7—FIRING RANGE OF SOUTH CAROLINA SHALE ONCE USED IN SEWER PIPE MANUFACTURE

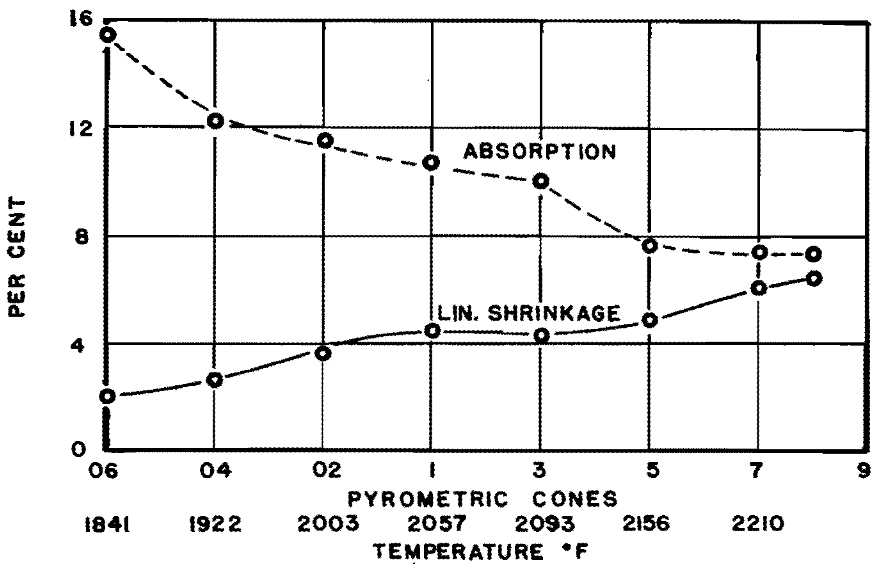

FIG. 8—FIRING RANGE OF A CONE 5 OHIO SEWER PIPE CLAY

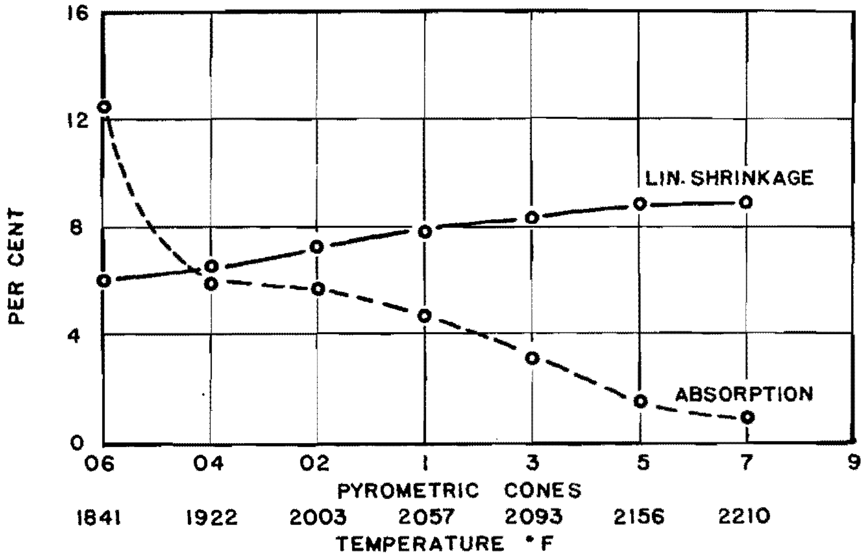

FIG. 9—FIRING RANGE OF A CONE 04 OHIO SEWER PIPE CLAY

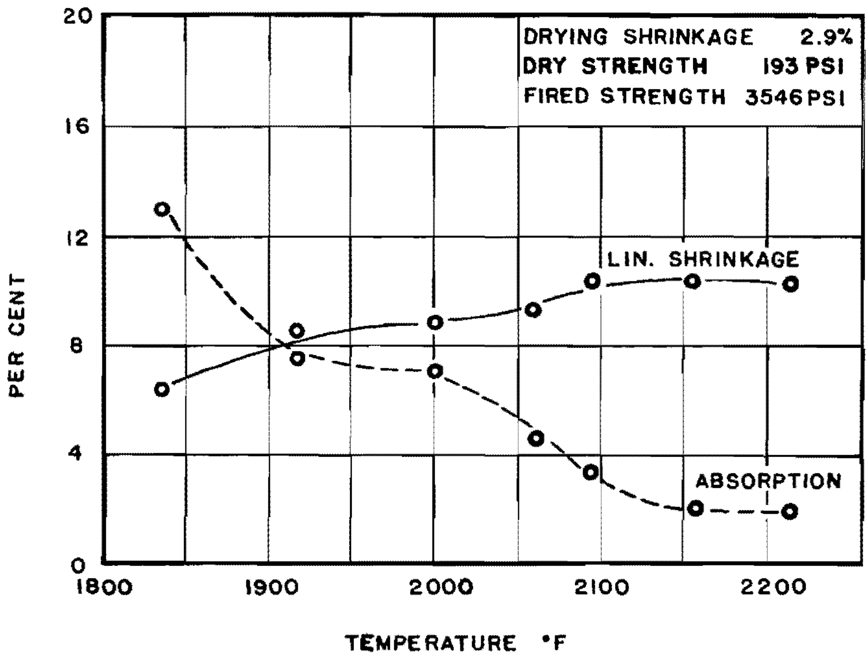

FIG. 10—FIRING RANGE OF AN OHIO PAVING BRICK CLAY

DESCRIPTION OF SAMPLES

Field descriptions, laboratory results, and comments on the quality and potential use for each sample tested in the course of this investigation are given on the following pages. All sample localities are also shown on Plate 1.

Sample RBJ-1

Location: Marlboro County; Cheraw Brick Works; 1.2 miles southeast of Kollock (Wallace).

Field description: Sample RBJ-1 is representative of the ordinary clay being used by the Cheraw Brick Works. A clay containing nodules of manganese (?) oxide is present nearby and is used also to some extent. These clays are river terrace deposits of probable Pleistocene age.

Laboratory results:

Dry transverse strength...986 lbs. per sq. inch
Extrusion strength.......8½ inches
Drying shrinkage........6.0% linear
Water of plasticity.......20.8%
Fired transverse strength..1402 lbs. per sq. inch

Temp. (°F)	*Total linear shrinkage (%)*	*Absorption (%)*	*Hardness*	*Color*
1900	7.8	9.9	soft	salmon
2000	9.3	8.4	hard	salmon
2100	9.3	8.1	hard	red
2200	10.9	6.4	hard	red
2300	10.9	5.3	hard	red

Remarks: This material is suitable for common brick, face brick, structural tile, drain tile, and flower pots. The sample extruded well and produced brick with a very high dry strength. Drying shrinkage and firing shrinkage were moderate. The test brick had slightly rough textures because of the presence of many quartz grains. A few cracks which were noted on the surface of the test brick were probably caused by the presence of the quartz.

Sample RBJ-2

Location: Marlboro County; Palmetto Brick Company; 2.6 miles southeast of Kollock (Wallace); 9.5 miles northwest of Bennettsville.

Field description: Sample was channel sample of 8 foot thick clay bed in pit about 1000 feet north of the plant.

Laboratory results:

Dry transverse strength...762 lbs. per sq. inch
Extrusion strength .... 8½ inches
Drying shrinkage .... 4.3% linear, 13.7% volume
Dry bulk density .... 1.88 gms./cc.
Apparent porosity 28.3%
Water of plasticity 18.7%
Shrinkage water 8.5%
Pore water 10.2%
Fired transverse strength..2440 lbs. per sq. inch

Temp. (°F)	*Total linear shrinkage (%)*	*Absorption (%)*	*Bulk density (gms./cc.)*	*Hardness*	*Color*
2050	7.0	11.8	1.98	soft	salmon
2150	8.0	10.3	1.99	hard	red
2200	8.4	8.3	2.07	hard	red
2250	8.8	8.6	2.13	hard	purple-red
2300	8.6	5.2	2.25	hard	brown
2350	10.0	1.3	2.22	hard	brown
2400	11.0	1.1	2.11	hard	black

Remarks: This material is suitable for the manufacture of common brick, face brick, drain tile, hollow tile, and flower pots. It has a high dry strength, extrusion strength, and fired strength. The material dried satisfactorily on a slow drying schedule but could not stand rapid drying. Drying shrinkage was low, and total shrinkage was moderate. The fired brick were free from cracks and produced very attractive red colors.

Sample RBJ-3

Location: Darlington County; from pit of Consumers' Brickyard (Darlington Brick Works) at northeast edge of Society Hill.

Field description: Apparently a river terrace deposit. The clay bed is about 8 feet thick and is overlain by less than a foot of soil.

Laboratory results:

Dry transverse strength...795 lbs. per sq. inch
Drying shrinkage.........6.2% linear
Fired transverse strength..1070 lbs. per sq. inch

Temp. (°F)	*Total linear shrinkage (%)*	*Absorption (%)*	*Hardness*	*Color*
1950	10.9	12.1	soft	salmon
2000	10.9	10.9	hard	salmon
2150	10.9	10.3	hard	red
2200	10.9	8.7	hard	red
2300	10.9	7.3	hard	red
2350	10.9	5.1	hard	purple
2400	12.5	4.2	hard	black

Remarks: This material is suitable for the manufacture of common brick, face brick, drain tile, flower pots, and possibly structural tile. It had a high dry strength, a medium fired strength, a long firing range, and produced brick free from cracks and attractive in appearance. The drying shrinkage of the clay was high, but this shrinkage could probably be decreased through the use of electrolytes. Firing shrinkage was uniform throughout the firing range.

Sample RBJ-4

Location: Darlington County; at west edge of road parallel to Atlantic Coast Line Railroad 2.7 miles north-northeast of Montclare; 9.7 miles north-northeast of Darlington.

Field description: Sample is thought to be representative of clay bed extending over several square miles in this area and northward to Robbins Neck. The clay bed is 5 feet or more in thickness and is covered by about a foot of soil.

Laboratory results:

Dry transverse strength...563 lbs. per sq. inch
Drying shrinkage.........6.5% linear
Fired transverse strength..2295 lbs. per sq. inch

Temp. (°F)	*Total linear shrinkage (%)*	*Absorption (%)*	*Hardness*	*Color*
2050	12.5	12.2	soft	salmon
2100	12.5	10.9	soft	salmon
2200	12.5	11.1	soft	salmon
2250	12.5	9.4	hard	red

Remarks: This material could be used in the manufacture of drain tile and common brick, but its high maturing temperature would detract from its usefulness. Brick fired to temperatures below 2250°F showed a bad tendency to crumble at the edges. The clay showed a high drying shrinkage but fired test brick were free from cracks.

Sample RBJ-5

Location: Marion County; J. D. Murchison Company brick plant at Blue Brick on Atlantic Coast Line Railroad about 1.6 miles northeast of Pee Dee; 7.4 miles west-northwest of Marion.

Field description: Sample was of ground clay ready for the extruder.

Laboratory results:

Dry transverse strength...818 lbs. per sq. inch
Extrusion strength ....9½ inches
Drying shrinkage.........3.5% linear, 18.4% volume
Dry bulk density ....1.89 gms./cc.
Apparent porosity........28.8%
Water of plasticity........20.9%
Shrinkage water 11.9%
Pore water 9.0%
Fired transverse strength..2568 lbs. per sq. inch

Temp. (°F)	*Total linear shrinkage (%)*	*Absorption (%)*	*Bulk density (gms./cc.)*	*Hardness*	*Color*
2050	10.2	11.7	2.04	soft	salmon
2100	10.6	11.1	2.05	hard	salmon
2150	10.8	11.1	2.04	hard	salmon
2200	10.8	10.9	2.05	hard	salmon
2250	10.6	9.0	2.12	hard	red
2300	10.6	7.2	2.18	hard	purple-red
2350	12.4	5.2	2.28	hard	brown

Remarks: This material would be suitable for the manufacture of common brick, face brick, flower pots, and drain tile. It differed from RBJ-6 in that it contained an appreciable quantity of fine quartz sand. This sand caused a desirable reduction in shrinkage but raised the maturing temperature and lowered the fired strength. Because of this difference in properties, RBJ-5 would be less desirable than RBJ-6 for use in structural tile, roofing tile, and floor tile. Material suitable for any of these products could probably be obtained, however, by selective mining and blending of the various clays in this area.

Sample RBJ-6

Location: Marion County; J. D. Murchison Company brick plant at Blue Brick on Atlantic Coast Line Railroad about 1.6 miles northeast of Pee Dee; 7.4 miles west-northwest of Marion.

Field description: Sample was from depth of 6 feet in pit about 500 feet northeast of company office.

Laboratory results:

Dry transverse strength...960 lbs. per sq. inch
Extrusion strength ....9 inches
Drying shrinkage.........6.1% linear, 20.7% volume
Dry bulk density ....1.86 gms./cc.
Apparent porosity........30.3%
Water of plasticity........22.2%
Shrinkage water 14.0%
Pore water 8.2%
Fired transverse strength..4555 lbs. per sq. inch

Temp. (°F)	*Total linear shrinkage (%)*	*Absorption (%)*	*Bulk density (gms./cc.)*	*Hardness*	*Color*
2050	12.0	5.2	2.23	hard	salmon
2100	11.6	2.4	2.31	hard	red
2150	12.2	0.8	2.33	hard	red
2200	12.0	0.3	2.34	hard	purple-red
2250	12.4	0.09	2.35	hard	purple-red
2300	12.6	1.5	2.19	hard	brown
2350	12.8	3.1	2.07	hard	brown
2400	13.0	4.3	1.99	hard	black

Remarks: This is one of the best clays known from the Coastal Plain section. It could be used to produce superior common brick, drain tile, flower pots, and structural tile. The pleasing fired colors and smooth texture would permit production of very attractive face brick. This clay could also be used as the principal ingredient for floor tile, roofing tile, and sewer pipe.

RBJ-6 had a very high dry strength and extruded very well. Fired strength was extremely high. Objectionable qualities of this material were high total shrinkage, poor resistance to rapid drying, and the development of some lamination structure in the fired brick. Slight bloating occurred at 2300°F.

Sample RBJ-7

Location: Florence County; at Mars Bluff on the Pee Dee River, 11.5 miles east of Florence.

Field description: Sample is representative of the dark gray to black clay layers interbedded in the Black Creek formation (Cooke, 1936, p. 28-30) exposed in the bluff of the Pee Dee River. The clay is overlain by 25 feet or more of sand at this locality but could probably be found nearer the surface elsewhere.

Laboratory results:

Dry transverse strength...1090 lbs. per sq. inch
Drying shrinkage.........15.5% linear
Water of plasticity........61%

Remarks: Sample RBJ-7 was similar to RBJ-20 but seemed to contain larger quantities of silt, which lowered its plasticity and gave it slightly better drying characteristics. Cracking during drying and subsequent bloating during slow firing prevented obtaining accurate values for both dry and fired properties.

Sample RBJ-7 required a higher temperature for vesiculation to occur and did not produce as much expansion or as uniform a bubble structure as did sample RBJ-20.

Sample RBJ-8

Location: Marion County; Marion Brick Company; just south of Atlantic Coast Line Railroad about 1.3 miles west of center of Marion.

Field description: Sample was from storage bin at Marion Brick Company plant and is thought to be representative of the clay available within 0.3 mile of the plant.

Laboratory results:

Dry transverse strength...482 lbs. per sq. inch
Extrusion strength ....8 inches
Drying shrinkage.........3.1% linear
Water of plasticity........26.4%
Fired transverse strength..931 lbs. per sq. inch

Temp. (°F)	*Total linear shrinkage (%)*	*Absorption (%)*	*Hardness*	*Color*
1900	9.3	17.6	soft	salmon
2000	9.3	15.0	soft	salmon
2100	9.3	14.3	soft	salmon
2200	10.9	13.6	soft	red
2300	10.9	13.3	soft	red

Remarks: This sample produced fired brick with very smooth surfaces, but an excessively high maturing temperature would hamper the use of this material for most products. The brick remained soft and porous even after firing to 2300°F. The addition of shale to this clay would probably produce an excellent raw material.

Sample RBJ-9

Location: Florence County; on Scott farm on west side of U. S. 52 approximately 1.1 miles south of Lynches River.

Field description: Six hand auger holes drilled August 13, 1946, in area approximately 1000 by 1100 feet indicate the presence of a bed of sandy and silty clay and clayey sand averaging about 6 feet in thickness and overlain by a foot or so of soil. Sample RBJ-9 is from a depth of 1 to 6.5 feet in auger hole number 6 and is thought to be typical of the clay in this deposit and in similar clay deposits that occur along the floodplain of Lynches River in the vicinity of Florence.

Laboratory results:

Dry transverse strength...377 lbs. per sq. inch
Drying shrinkage.........none
Fired transverse strength..78 lbs. per sq. inch

Temp. (°F)	*Total linear shrinkage (%)*	*Absorption (%)*	*Hardness*	*Color*
2050	3.1	17.0	soft	red
2100	3.1	15.8	soft	red
2150	3.1	15.3	soft	red
2200	3.1	16.0	soft	red
2300	3.1	9.6	soft	pink

Remarks: Sample RBJ-9 contained excessive amounts of quartz sand, which would prohibit the use of this material in the manufacture of structural clay products. The notable defects of this sample are the very low fired strength, the very high maturing temperature, and the pronounced tendency to featheredge.

Sample RBJ-10

Location: Lee County; just north of Atlantic Coast Line Railroad 1.2 miles northeast of Lynchburg.

Field description: Sample is composite from five points at approximate 50 foot intervals along ditch bank and is thought to be representative of 4 foot thick clay bed present beneath about a foot of soil in this area. Similar material occurs intermittently for several miles to northwest, between Lynchburg-Bishopville road and Lynches River.

Laboratory results:

Dry transverse strength...413 lbs. per sq. inch
Extrusion strength.......9 inches
Drying shrinkage.........3.3% linear, 12.3% volume
Dry bulk density.........1.98 gms./cc.
Apparent porosity........21.6%
Water of plasticity........18.2%
Shrinkage water.........7.1%
Pore water..............11.1%
Fired transverse strength..1343 lbs. per sq. inch

Temp. (°F)	*Total linear shrinkage (%)*	*Absorption (%)*	*Bulk density (gms./cc.)*	*Hardness*	*Color*
2050	1.6	14.6	1.93	soft	pink
2150	3.6	13.6	1.95	soft	pink-tan
2250	3.2	13.4	1.95	soft	light tan
2350	4.6	12.6	1.97	hard	light tan
2400	5.6	11.8	1.99	hard	light tan

Remarks: This material appeared to be similar to RBJ-11 but had some noticeable improvements. It extruded well and developed a high dry strength, almost twice that of RBJ-11. Though containing quartz it produced brick with a surface free from cracking. Drying shrinkage was low, and the clay withstood the rapid drying treatment without cracking. Total shrinkage was very low, and the test brick had a moderate fired strength.

This sample merits further investigation to determine the possibility of its use in the manuafacture of flue lining and other refractories. Washing of this clay would probably produce a good raw material for artware. RBJ-10 could also be used in the manufacture of buff face brick.

Sample RBJ-11

Location: Kershaw County; Hannah Dixon property, 4.0 miles south of Bethune; on dirt road 0.3 mile north of S. C. 15.

Field description: Impure, silty kaolin, from the Tuscaloosa formation or a creek floodplain deposit formed from reworked Tuscaloosa formation. RBJ-11 is from a depth of 0.3 to 3.8 feet in auger hole no. 1 drilled 6-30-49 by Buie.

Laboratory results:

Dry transverse strength...262 lbs. per sq. inch
Extrusion strength ....8½ inches
Drying shrinkage.........4.0% linear, 13.8% volume
Dry bulk density ....1.91 gms./cc.
Apparent porosity........26.2%
Fired transverse strength..834 lbs. per sq. inch

Temp. (°F)	*Total linear shrinkage (%)*	*Absorption (%)*	*Bulk density (gms./cc.)*	*Hardness*	*Color*
2100	7.8	17.6	1.87	soft	buff
2200	7.8	19.5	1.85	hard	buff
2300	8.2	19.1	1.93	hard	buff
2400	7.6	20.0	1.90	hard	buff

Remarks: If carefully cleaned, this material would be suitable for artware, refractories, and buff face brick. As it is, it contains abundant quartz sand which caused the fired brick to develop a maze of surface cracks.

RBJ-11 had a very high dry strength in comparison to other buff-firing clays of the State, and the dry strength would probably be increased if the quartz sand were removed. The sample extruded beautifully and resisted rapid drying without cracking. It was comparatively refractory, giving no indication of a reduction in porosity even after firing at 2400°F.

Sample RBJ-12

Location: Kershaw County; Hannah Dixon property, 4.0 miles south of Bethune; on dirt road 0.3 mile north of S. C. 15.

Field description: Impure silty kaolin from the Tuscaloosa formation or a creek floodplain deposit formed from reworked Tuscaloosa formation. RBJ-12 is from a depth of 3.8 to 6.5 feet in auger hole no. 1 drilled 6-30-49 by Buie.

Laboratory results:

Dry transverse strength . . . 180 lbs. per sq. inch
Extrusion strength . . . . 4½ inches
Drying shrinkage . . . . 0 linear, 3.7% volume
Dry bulk density . . . . 2.03 gms./cc.
Apparent porosity 21.0%
Water of plasticity 11.9%
Shrinkage water 1.9%
Pore water 10.0%
Fired transverse strength . . 193 lbs. per sq. inch

Temp. (°F)	*Total linear shrinkage (%)*	*Absorption (%)*	*Bulk density (gms./cc.)*	*Hardness*	*Color*
2100	0	14.4	1.94	soft	cream
2200	0.6	14.5	1.93	soft	cream
2300	1.6	14.4	1.94	soft	cream
2600	0.6	14.5	1.92	soft	tan

Remarks: The sample was predominantly quartz sand with a small quantity of clay. The high sand content would prevent the use of this material for most purposes. The refractory nature of this material is indicated by its withstanding a temperature of 2600°F without noticeable reduction in absorption.

Sample RBJ-13

Location: Kershaw County; Hannah Dixon property, 4.0 miles south of Bethune; on dirt road 0.3 mile north of S. C. 15.

Field description: Impure, silty kaolin from the Tuscaloosa formation or a creek floodplain deposit formed from reworked Tuscaloosa formation. RBJ-13 is from a depth of 0.5 to 3.8 feet in auger hole no. 2 drilled 6-30-49 by Buie.

Laboratory results:

Dry transverse strength...158 lbs. per sq. inch
Extrusion strength ....6¾ inches
Drying shrinkage.........3.4% linear, 11.7% volume
Dry bulk density ....1.78 gms./cc.
Water of plasticity........24.5%
Shrinkage water 7.4%
Pore water 17.1%
Fired transverse strength..1039 lbs. per sq. inch

Temp. (°F)	*Total linear shrinkage (%)*	*Absorption (%)*	*Bulk density (gms./cc.)*	*Hardness*	*Color*
2050	4.4	19.8	1.78	soft	cream
2150	6.4	16.9	1.88	hard	cream
2250	6.4	16.1	1.89	hard	cream
2300	7.6	15.8	1.90	hard	cream
2600	7.2	15.7	1.90	hard	cream

Remarks: RBJ-13 produced fired brick that were light cream in color and that contained a few craze cracks around particles of quartz. The brick became hard and had a good ring at 2150°F and yet they showed very little sign of glass formation at 2600°F. This material would probably be suitable for the manufacture of fire brick and flue lining.

RBJ-13 had a low drying shrinkage and withstood the rapid drying treatment without cracking.

Sample RBJ-14

Location: Kershaw County; Hannah Dixon property, 4.0 miles south of Bethune; on dirt road 0.3 mile north of S. C. 15.

Field description: Impure, silty kaolin from the Tuscaloosa formation or a creek floodplain deposit formed from reworked Tuscaloosa formation. RBJ-14 is from a depth of 3.8 to 5.5 feet in auger hole no. 2 drilled 6-30-49 by Buie.

Laboratory results:

Extrusion strength ....9 inches
Drying shrinkage.........0.5% linear, 14.5% volume
Dry bulk density ....1.82 gms./cc.
Apparent porosity........30.0%
Water of plasticity........26.6%
Shrinkage water 9.5%
Pore water 17.1%
Fired transverse strength..664 lbs. per sq. inch

Temp. (°F)	*Total linear shrinkage (%)*	*Absorption (%)*	*Bulk density (gms./cc.)*	*Hardness*	*Color*
2050	6.0	20.7	1.75	soft	
2150	6.2	19.6	1.78	soft	
2200	6.4	18.8	1.80	soft	tan
2300	7.0	18.1	1.81	hard	tan
2600	6.0	15.4	1.88	hard	light brown

Remarks: Sample RBJ-14 was similar to RBJ-11. The material extruded nicely and resisted rapid drying without cracking. The sample was very refractory, being able to withstand 2600°F without increase in shrinkage or very much reduction in absorption.

The refractory nature of this clay together with its substantial content of quartz sand caused it to have low fired strength. Removal of the sand by washing might produce a suitable clay for artware and light-colored face brick.

Sample RBJ-15

Location: Kershaw County; on U. S. 1 about 2.9 miles west-southwest of Cassatt.

Field description: Sample is from bed of sandy kaolin. These kaolin deposits are common in the Tuscaloosa formation in a belt extending from Aiken to Cheraw. They may be up to 40 feet thick and usually extend over several acres.

Laboratory results:

Dry transverse strength...117 lbs. per sq. inch
Extrusion strength ....8½ inches
Drying shrinkage.........3.1% linear, 14.9% volume
Dry bulk density ....1.87 gms./cc.
Apparent porosity........28.3%
Water of plasticity........23.1%
Shrinkage water 8.0%
Pore water 15.2%
Fired transverse strength..1954 lbs. per sq. inch

Temp. (°F)	*Total linear shrinkage (%)*	*Absorption (%)*	*Bulk density (gms./cc.)*	*Hardness*	*Color*
2150	6.0	13.8	1.85	soft	cream
2250	....	13.5	1.85	soft	cream
2350	7.0	12.9	1.87	hard	cream
2400	7.0	12.0	1.89	hard	cream

Remarks: This material is impure kaolin. It might be used in artware mixtures, in the manufacture of light-colored face brick, or as an additive to other clays to lengthen their firing range. It displays good extrusion qualities but has a low dry strength and a poor resistance to rapid drying. The fired strength of test brick was high, and surfaces of the brick were free of small cracks. The brick showed a tendency to split lengthwise, however. A temperature of 2350°F was required to make hard brick.

Sample RBJ-16

Location: Kershaw County; 4.0 miles south-southwest of center of Camden; 0.6 mile west of Wateree River; 2.7 miles southeast of Lugoff.

Field description: Sample is of 3.5 foot thick bed of silty clay. Probably a floodplain deposit of the Wateree River.

Laboratory results:

Dry transverse strength...307 lbs. per sq. inch
Extrusion strength ....8½ inches
Drying shrinkage.........4.6% linear, 8.2% volume
Dry bulk density ....1.77 gms./cc.
Apparent porosity........31.3%
Water of plasticity........22.5%
Shrinkage water 5.1%
Pore water 17.6%
Fired transverse strength..2402 lbs. per sq. inch

Temp. (°F)	*Total linear shrinkage (%)*	*Absorption (%)*	*Bulk density (gms./cc.)*	*Hardness*	*Color*
2100	3.0	15.7	1.88	soft	red
2150	6.0	13.8	1.94	hard	dark red
2200	6.0	10.4	2.06	hard	dark red
2250	6.1	6.8	2.18	hard	purple-red
2300	6.6	1.3	2.25	hard	black

Remarks: This material could be used in the manufacture of common brick, face brick, drain tile, and hollow tile. It had moderate drying shrinkage, dry strength, and fired strength but behaved poorly during rapid drying. Total shrinkage was low, and the fired brick were free from cracks.

Sample RBJ-17

Location: Sumter County; Sumter Brick Works; between Atlantic Coast Line Railroad and U. S. 76 in the eastern edge of Sumter.

Field description: Sample is representative of 5 to 8 foot thick bed of sandy clay and clayey sand present within 3 feet of the surface over several square miles in this area. Sumter Brick Works used this material until about 1941, when operations ceased.

Laboratory results:

Dry transverse strength...611 lbs. per sq. inch
Extrusion strength ....9¾ inches
Drying shrinkage.........6.74% linear
Fired transverse strength..933 lbs. per sq. inch

Temp. (°F)	Total linear shrinkage (%)	Absorption (%)	Bulk density (gms./cc.)	Hardness	Color
2100	6.8	14.2	1.94	soft	salmon
2200	7.6	14.0	1.95	soft	salmon
2300	7.6	13.7	1.94	soft	salmon
2400	7.6	14.3	1.91	soft	purple

Remarks: This material has a high content of quartz sand which would prevent its use for most purposes. Its only desirable feature is the attractive purple colors obtained at higher temperatures.

Sample RBJ-18

Location: Sumter County; 2.4 miles northwest of Wedgefield; 12 miles west of Sumter.

Field description: Sample is fairly representative of a 5 to 15 foot thick bed of silty clay extending over an area about 2.0 miles long by 0.75 mile wide. The clay is a terrace deposit of the Wateree River.

Laboratory results:

Dry transverse strength...320 lbs. per sq. inch
Drying shrinkage.........8.6% linear
Water of plasticity........32.4%
Fired transverse strength..1019 lbs. per sq. inch

Temp. (°F)	*Total linear shrinkage (%)*	*Absorption (%)*	*Hardness*	*Color*
2000	11.4	17.9	soft	salmon
2100	12.8	15.5	soft	salmon
2200	13.4	14.4	soft	pale red

Remarks: This material contained large quantities of quartz sand and consequently had a low dry strength and a low fired strength. The sand also caused the development of many hairline cracks over the surface of the material. This would be objectionable in many structural products.

Although RBJ-18 did produce a tough extruded column, it showed a tendency to featheredge during extrusion. Also, a very high firing temperature would be required to obtain sufficient strength in the units (Fired transverse strength was only 582 lbs. per sq. inch for test brick fired to 2100°F).

Additions of shale to this material would probably permit the manufacture of good structural products. Without such additions, the defects of the material would be very difficult to overcome. There is reason to expect variation in the sand content of the clay in this deposit, and this variation would cause a wide range in the properties of the material. Plasticity, dry strength, and fired properties would be improved by a reduction in the sand content; but drying problems might be increased.

Sample RBJ-19

Location: Lexington County; Guignard Brick Works, West Columbia.

Field description: Sample is composite from storage bin on 8-25-49 and is representative of alluvial clay mined at that time from river terrace deposits about 3 miles south-southeast of West Columbia. These deposits became too sandy and were subsequently abandoned in favor of shale deposits a few miles west-northwest of the Guignard plant. Clays similar to RBJ-19 could probably be found at other points along the Congaree River southeast of Columbia.

Laboratory results:

Dry transverse strength...608 lbs. per sq. inch
Extrusion strength ....10 inches
Drying shrinkage..........3.79% linear
Fired transverse strength..2661 lbs. per sq. inch

Temp. (°F)	*Total linear shrinkage (%)*	*Absorption (%)*	*Bulk density (gms./cc.)*	*Hardness*	*Color*
2050	7.6	11.5	2.03	hard	brown-red
2100	8.2	9.9	2.09	hard	brown-red
2150	7.4	8.8	2.13	hard	brown-red
2200	7.6	7.1	2.19	hard	red
2250	7.6	5.6	2.15	hard	purple
2300	6.2	3.8	2.21	hard	black
2350	7.2	....	2.03	hard	black
2400	8.6	4.9	2.18	hard	brown

Remarks: This material would be suitable for the manufacture of face brick, common brick, drain tile, hollow tile, flower pots, and roofing tile. It developed the characteristic internal structure of a highly siliceous clay but contained sufficient fluxes to produce a hard brick over a long firing range. Firing shrinkage was uniform throughout the firing range, and the texture of the fired brick was smooth. There was a slight tendency to bloat at 2350°F. Fired strength was very high. Resistance to the rapid drying treatment was fair.

Sample RBJ-20

Location: Orangeburg County; Harley Mill Pond, 3.5 miles southwest of the town of North.

Field description: Sample is of green bentonite clay of Eocene age exposed in the bluff bank on the south side of the mill pond. This clay bed is approximately 15 feet thick at this locality and is known to extend over many square miles in this area. It is commonly overlain by 10 to 50 feet or so of sand and sandy clay, but places could probably be found where it is at or within a few feet of the surface. Deposits of similar clay are known at many localities in northern Orangeburg and southern Calhoun Counties.

Laboratory results:

Dry transverse strength...1000 lbs. per sq. inch
Drying shrinkage..........9.8% linear
Water of plasticity........51%
Fired absorption..........12.6% (2000° F)
Fired transverse strength..1610 lbs. per sq. inch (2000° F)

Remarks: Sample RBJ-20 was a highly plastic clay resembling bentonite in many of its properties. It extruded beautifully but showed such poor drying behavior that it was impossible to produce dry specimens free from cracks. The cracking of the specimens prevented obtaining accurate measurements of properties, and therefore the results listed above are only approximate. However, the sample did indicate unusually high dry strength and high drying shrinkage. Additions of small quantities of this material would greatly improve the plasticity and dry strength of "lean" clays.

This material showed excellent bloating, even when fired on very slow schedules. It would probably make a good lightweight aggregate, although the high water of plasticity, difficult drying, and high shrinkage would probably make it an expensive raw material for this product.

Sample RBJ-21

Location: Orangeburg County; property of E. E. Williams, 1.5 miles northeast of Jamison.

Field description: Sample is representative of a 5 to 15 foot thick blanket-like deposit of mottled yellow-brown-red sandy and gravelly clay present at the surface of the ground over many square miles in this area. This clay deposit is a residuum from beds thought to be the shoreward equivalent of the marine Hawthorn formation of Miocene age.

Laboratory results:

Dry transverse strength...169 lbs. per sq. inch
Drying shrinkage.........10.0% linear
Water of plasticity........40.0%
Fired transverse strength..548 lbs. per sq. inch

Temp. (°F)	*Total linear shrinkage (%)*	*Absorption (%)*	*Hardness*	*Color*
2000	13.1	23.5	soft	salmon
2100	15.4	18.1	soft	salmon
2200	15.2	12.4	soft	salmon

Remarks: This was a very poor material. It had poor extrusion characteristics, a very high drying shrinkage, and low dry strength. Its fired strength was very poor, and fired specimens showed considerable cracking. The material is relatively refractory. The only interesting feature of RBJ-21 is that it showed a lighter range of colors than is customary in normally red firing structural products. The color almost approached buff at lower firing temperatures.

Sample RBJ-22

Location: Jasper County; Deerfield Sand Company; on U. S. 601 about 7.7 miles north of Hardeeville.

Field description: Sample is from 5 to 8 foot thick clay layer at surface and overlying sand deposit. This clay must be removed to get to the sand.

Laboratory results:

Dry transverse strength...791 lbs. per sq. inch
Extrusion strength ....10 inches
Drying shrinkage.........7.1% linear, 21.9% volume
Dry bulk density ....1.96 gms./cc.
Apparent porosity........26.7%
Water of plasticity....... 31.0%
Shrinkage water 14.3%
Pore water 16.7%
Fired transverse strength..4000 lbs. per sq. inch

Temp. (°F)	Total linear shrinkage (%)	Absorption (%)	Bulk density (gms./cc.)	Hardness	Color
2000	11.6	8.0	2.17	hard	salmon
2100	11.0	8.2	2.15	hard	salmon
2200	11.8	7.4	2.20	hard	salmon
2300	11.8	6.9	2.23	hard	red
2400	13.0	5.8	2.26	hard	yellow-brown

Remarks: RBJ-22 suffered from high drying shrinkage, inability to resist rapid drying, and severe lamination. If these defects could be overcome, this material would be suitable in the manufacture of common brick, face brick, drain tile, hollow tile, roofing tile, and flower pots. A previous sample from this locality displayed unusual fired colors of brilliant orange, deep red, and gray. Though RBJ-22 failed to produce these brilliant colors, it did produce some very pleasing ones. Possibly the use of a reducing fire or careful selection of material would achieve the production of very unusual face brick.

RBJ-22 produced brick free from cracks and had a very high dry strength, an extremely high fired strength, and a very long vitrification range of over 400°F.

Sample RBJ-23

Location: Jasper County; Deerfield Sand Company; on U. S. 601 about 7.7 miles north of Hardeeville.

Field description: Same as for RBJ-22.

Laboratory results:

Dry transverse strength...649 lbs. per sq. inch
Extrusion strength ....10 inches
Drying shrinkage.........5.7% linear, 20.4% volume
Dry bulk density ....1.95 gms./cc.
Apparent porosity........26.5%
Water of plasticity........27.1%
Shrinkage water 13.1%
Pore water 14.0%
Fired transverse strength..2733 lbs. per sq. inch

Temp. (°F)	*Total linear shrinkage (%)*	*Absorption (%)*	*Bulk density (gms./cc.)*	*Hardness*	*Color*
2000	9.8	11.3	2.06	soft	salmon
2100	10.2	11.5	2.05	soft	salmon
2200	10.2	10.8	2.08	soft	salmon
2250	12.2	10.3	2.09	hard	red
2300	11.6	9.3	2.13	hard	red
2400	12.2	5.7	2.27	hard	brown

Remarks: RBJ-23 was similar in its properties to RBJ-22 except that it required a higher maturing temperature and produced brick with a lower strength.

Sample RBJ-24

Location: Jasper County; 2.5 miles south-southeast of Coosawhatchie; 6.2 miles northeast of Ridgeland.

Field description: Sample is representative of a clay bed averaging about 5 feet in thickness over many square miles in this area. The clay is overlain by less than 3 feet of soil and in many places overlies a bentonite bed up to 20 feet thick. Similar clay is known to occur over several square miles just north of Hardeeville in this county.

Laboratory results:

Dry transverse strength...1180 lbs. per sq. inch
Extrusion strength ....7½ inches
Drying shrinkage..........9.8% linear
Fired transverse strength..1058 lbs. per sq. inch

Temp. (°F)	*Total linear shrinkage (%)*	*Absorption (%)*	*Hardness*	*Color*
2000	11.7	13.4	soft	salmon
2240	11.8	12.4	soft	red

Remarks: This material showed good extrusion qualities, a very high dry strength, and a high drying shrinkage. The sandiness of this material caused it to have a low firing shrinkage and low fired strength. High temperatures would be required to produce hard, strong units.

Sample RBJ-25

Location: Charleston County; 0.7 mile south of Meggate Station on the Atlantic Coast Line Railroad; about 18 miles west-southwest of Charleston.

Field description: Sample is from a depth of 1.0 to 3.5 feet in a hand auger hole. The clay bed lies on sandy silt and is overlain by about 1 foot of soil. At high tide this clay bed is awash.

Laboratory results:

Dry transverse strength...264 lbs. per sq. inch
Extrusion strength ....4 inches
Drying shrinkage..........4.3% linear, 14.2% volume
Dry bulk density ....1.92 gms./cc.
Apparent porosity........14.4%
Water of plasticity........24.6%
Shrinkage water 7.4%
Pore water 17.2%

Temp. (°F)	Total linear shrinkage (%)	Absorption (%)	Bulk density (gms./cc.)	Hardness	Color
2100	8.6	21.3	1.69	soft	red
2200	8.6	20.1	1.75	soft	red
2300	8.2	17.0	1.87	hard	red
2350	10.8	9.8	2.04	hard	black
2400	13.6	1.7	2.15	hard	brown

Remarks: This material is very sandy, but it contains sufficient fluxes to vitrify at 2350°F. The only desirable attributes are a very vivid fired color and a shaggy appearance. These might make this clay suitable for the manufacture of face brick.

Sample RBJ-26

Location: Dorchester County; just south of Southern Railroad at Drainland, about 2.4 miles northwest of Summerville.

Field description: Sample is composite from 6.5 foot deep auger hole. This clay bed has essentially no overburden and is over 6 feet thick. It extends over many acres of flat, fairly open ground in this area.

Laboratory results:

Dry transverse strength...473 lbs. per sq. inch
Extrusion strength ....4½ inches
Water of plasticity........22.2%
Fired transverse strength..1012 lbs. per sq. inch

Temp. (°F)	*Total linear shrinkage (%)*	*Absorption (%)*	*Hardness*	*Color*
1900	7.8	16.9	soft	red
2000	7.8	16.5	soft	red
2100	7.8	15.7	soft	red
2200	7.8	15.5	soft	red
2300	7.8	15.4	soft	red

Remarks: This material would be suitable for drain tile, common brick, and face brick. The test brick had very smooth textures and were free from cracks but maintained a high porosity to 2300°F.

Sample RBJ-27

Location: Dorchester County; Salisbury Brick Works, northeast edge of Summerville.

Field description: Sample is from brick works storage bin and is thought to be representative of clay used by Salisbury Brick Works. The clay deposit is about 5 feet thick and is overlain by about 1 foot of soil.

Laboratory results:

Dry transverse strength...443 lbs. per sq. inch
Extrusion strength ....9 inches
Drying shrinkage.........6.8% linear, 18.2% volume
Dry bulk density ....1.93 gms./cc.
Apparent porosity........23.1%
Water of plasticity........25.9%
Fired transverse strength..872 lbs. per sq. inch

Temp. (°F)	*Total linear shrinkage (%)*	*Absorption (%)*	*Bulk density (gms./cc.)*	*Hardness*	*Color*
2050	6.0	19.5	1.77	soft	red
2150	6.8	19.3	1.78	soft	red
2250	6.8	19.3	1.76	soft	red
2350	7.2	17.6	1.81	soft	red
2450	8.2	14.5	....	soft	brown-red

Remarks: This material could be used in the manufacture of common brick, face brick, and drain tile; but it has some major defects. A very high maturing temperature would be required to produce a hard, strong brick. Test brick fired to lower temperatures had a high absorption and tended to crumble at the edges.

The clay cracked severely when exposed to the rapid drying treatment but dried satisfactorily at the slower rate. Dry strength was high, firing shrinkage was low, and fired strength was low. Fired test brick developed very attractive colors and had smooth, crack-free surfaces.

Sample RBJ-28

Location: Berkeley County; on S. C. 9 about 1.3 miles southeast of Strawberry; about 7.6 miles south of Moncks Corner.

Field description: Sample RBJ-28 is of reddish clay from 1 to 3 feet below the surface. The red clay grades downward into gray clay at a depth of about 3 feet. Sample RBJ-29 is of the gray material at a depth of about 4 feet. These two samples are representative of the "Spring Grove" type clays of Medway Plantation (Robinson and Johnson, 1960, p. 9). These clays are very widespread in this part of Berkeley County and are probably marine deposits of Pleistocene age. They are up to 12 feet and possibly more in thickness but can be expected to interfinger and grade both vertically and laterally into deposits of fine-grained clayey sand and consequently may be irregular and unpredictable in outline.

Laboratory results:

Dry transverse strength...944 lbs. per sq. inch
Extrusion strength ....9½ inches
Drying shrinkage.........8.1% linear, 38.5% volume
Dry bulk density ....2.05 gms./cc.
Apparent porosity........14.5%
Water of plasticity........33.9%
Shrinkage water 18.8%
Pore water 15.1%
Fired transverse strength..2829 lbs. per sq. inch

Temp. (°F)	*Total linear shrinkage (%)*	*Absorption (%)*	*Bulk density (gms./cc.)*	*Hardness*	*Color*
2050	12.0	12.7	2.00	soft	salmon
2200	11.2	12.7	2.00	soft	salmon
2300	12.2	12.2	2.03	hard	red
2350	12.6	12.2	2.01	hard	purple
2400	12.4	11.6	2.04	hard	purple

Remarks: This material would be suitable for the manufacture of face brick, common brick, drain tile, and hollow tile. Extrusion qualities of the sample tested were good, and the dry strength was very high. Fired strength was also high, and colors of the fired brick were very attractive.

Undesirable characteristics of this material are a poor resistance to rapid drying, a tendency to warp when dried slowly, high drying shrinkage, and the high firing temperature required to produce hard brick. These defects could possibly be overcome through admixture of other material, but they would in any case require careful consideration in the use of this material for structural clay products.

Sample RBJ-29

Location: Berkeley County; same as RBJ-28.

Field description: Same as RBJ-28.

Laboratory results:

Dry transverse strength...1479 lbs. per sq. inch
Extrusion strength ....9½ inches
Drying shrinkage..........5.7% linear
Water of plasticity........23.4%
Shrinkage water 11.6%
Pore water 11.8%
Fired transverse strength..2483 lbs. per sq. inch

Temp. (°F)	*Total linear shrinkage (%)*	*Absorption (%)*	*Bulk density (gms./cc.)*	*Hardness*	*Color*
2050	10.4	12.1	1.98	soft	salmon
2150	11.4	11.6	2.03	soft	salmon
2200	10.8	10.8	2.04	hard	red
2250	7.6	10.7	2.06	hard	purple
2300	12.4	8.6	2.13	hard	purple

Remarks: Except for having a lower maturing temperature, RBJ-29 is very similar to RBJ-28.

Sample RBJ-30

Location: Berkeley County; abandoned pit of St. Stephen Brick Works; 1.3 miles north-northeast of St. Stephen.

Field description: Sample is representative of 5 foot thick clay bed overlain by about 1 foot of soil. This clay deposit is present over many acres along the south edge of the Santee River swamp in this area.

Laboratory results:

Dry transverse strength...590 lbs. per sq. inch
Drying shrinkage..........7.7% linear
Water of plasticity........28%
Fired transverse strength..3084 lbs. per sq. inch

Temp. (°F)	*Total linear shrinkage (%)*	*Absorption (%)*	*Hardness*	*Color*
2000	12.0	11.3	soft	salmon
2100	12.1	11.0	soft	salmon
2200	13.4	6.7	hard	deep red

Remarks: This clay appears to be an excellent raw material for brick manufacture. Its only liability would be high drying shrinkage and somewhat difficult drying behavior. The sample extruded very nicely and showed good dry strength and excellent fired strength. It is possible to fire this material to less than 10 percent absorption; and very nice, deep red colors are produced.

Sample RBJ-31

Location: Williamsburg County; on U. S. 521 about 1.4 miles southeast of junction with S. C. 377; about 6.4 miles south-southeast of Kingstree.

Field description: Sample is composite from hand auger hole and channel sample in ditch and is representative of interval from 1 to 6 feet. Soil cover here is about 1 foot. Similar clays probably underlie extensive flat areas of this sort in the vicinity of Greeleyville and Lanes in Williamsburg County. These clay deposits are probably Pleistocene in age and marine in origin.

Laboratory results:

Dry transverse strength...371 lbs. per sq. inch
Extrusion strength ....10 inches
Drying shrinkage.........7.4% linear, 21.7% volume
Dry bulk density ....1.84 gms./cc.
Apparent porosity........31.6%
Water of plasticity........30.7%
Fired transverse strength..586 lbs. per sq. inch

Temp. (°F)	*Total linear shrinkage (%)*	*Absorption (%)*	*Bulk density (gms./cc.)*	*Hardness*	*Color*
2000	11.6	14.4	1.98	soft	salmon
2100	12.2	14.6	1.96	soft	salmon
2200	10.8	14.2	1.98	soft	salmon
2250	11.4	13.8	1.99	soft	red
2300	12.2	13.7	2.02	hard	red
2400	11.4	13.7	2.00	hard	purple

Remarks: The sample displayed good workability and resisted rapid drying without cracking in spite of its high drying shrinkage. However, this material is undesirable for structural clay products because the high content of quartz sand would cause serious defects in the fired brick. Test brick were covered with small cracks, and the ends of the specimens displayed severe lamination. The maturing temperature of 2300°F is very high for use in the manufacture of common brick.

Sample RBJ-32

Location: Williamsburg County; on northwest side of S. C. 41 at junction with U. S. 17-A; opposite Gridiron Chapel at junction of Cedar Creek and S. C. 41; about 23 miles southeast of Kingstree.

Field description: Sample is from auger hole through 4 foot thick bed of gray, slightly sandy clay overlain by about 7 feet of buff to mottled orange and red clayey sand. Top of bed sampled is at bottom of road cut exposure. The bed sampled may be a bedded deposit of Teritiary age, and the overlying mottled clayey sand is probably a marine deposit of Pleistocene age.

Laboratory results:

Dry transverse strength...883 lbs. per sq. inch
Extrusion strength ....9¼ inches
Drying shrinkage.........8.3% linear, 24.3% volume
Dry bulk density ....1.89 gms./cc.
Apparent porosity........32.4%
Water of plasticity........23.6%
Shrinkage water 17.0%
Pore water 6.6%
Fired transverse strength..2418 lbs. per sq. inch

Temp. (°F)	*Total linear shrinkage (%)*	*Absorption (%)*	*Bulk density (gms./cc.)*	*Hardness*	*Color*
2050	10.0	10.6	1.97	soft	salmon
2150	10.8	9.7	2.00	soft	salmon
2200	11.0	9.0	2.03	hard	red
2300	11.0	7.7	2.22	hard	tan-red
2350	11.6	6.8	2.08	hard	brown
2400	12.4	4.9	2.15	hard	tan

Remarks: This material had a low, uniform shrinkage. The fired brick were free from cracks, and the unusual colors obtained at higher temperatures suggest the desirability of this material for face brick. Dry and fired strengths were high. The material could probably be used in the manufacture of drain tile and common brick.

Disadvantages of this material were high drying shrinkage, high maturing temperature, and drying troubles. Samples cracked badly when exposed to rapid drying and warped when dried at a slow rate.

Sample RBJ-33

Location: Georgetown County; on U. S. 17-A about 8.2 miles west-southwest of Sampit; 0.7 mile west of Saints Delight Church; 8.4 miles south of Andrews.

Field description: Sample RBJ-33 is a composite of an 18 inch thick exposure in the ditch bank and an additional 30 inches from an auger hole. The 4 foot thick clay bed overlies clayey sand and is overlain by about 1 foot of clayey, silty soil. Much of the flat, lowlying land in the vicinity of Sampit is thought to be underlain by this type of clay deposit.

Laboratory results:

Dry transverse strength...623 lbs. per sq. inch
Extrusion strength ....9½ inches
Drying shrinkage.........7.0% linear, 21.0% volume
Dry bulk density ....1.89 gms./cc.
Water of plasticity........27.7%
Shrinkage water 14.1%
Pore water 13.6%
Fired transverse strength..1833 lbs. per sq. inch

Temp. (°F)	*Total linear shrinkage (%)*	*Absorption (%)*	*Bulk density (gms./cc.)*	*Hardness*	*Color*
2050	10.0	14.8	1.95	soft	salmon
2100	10.0	14.3	1.97	soft	salmon
2150	9.0	14.2	1.97	hard	salmon
2200	9.6	13.5	1.98	hard	salmon
2250	10.8	13.1	1.99	hard	salmon
2300	11.4	12.5	2.01	hard	red

Remarks: This clay would be suitable for the manufacture of drain tile, common brick, and face brick; but a high maturing temperature would be required, and care would have to be exercised in drying because of a tendency to crack badly when dried too rapidly. The material has a very high dry strength and a high fired strength. The fired test brick were free from cracks; and the surface texture was rough, probably because of the presence of quartz sand.

Sample RBJ-34

Location: Georgetown County; about 300 yds. south of Seaboard Air Line Railroad 3.4 miles east of Andrews; from old pits formerly worked for brick clay.

Field description: Sample is thought to be representative of clay deposit extending over a square mile or more both north and south of the railroad.

Laboratory results:

Dry transverse strength...1148 lbs. per sq. inch
Extrusion strength ....9½ inches
Drying shrinkage.........6.8% linear, 21.0% volume
Dry bulk density ....1.99 gms./cc.
Apparent porosity........24.8%
Water of plasticity........25.5%
Shrinkage water 12.8%
Pore water 12.7%
Fired transverse strength..1807 lbs. per sq. inch

Temp. (°F)	*Total linear shrinkage (%)*	*Absorption (%)*	*Hardness*	*Color*
2100	10.9	10.9	soft	salmon
2200	10.9	11.3	hard	red
2300	10.9	11.1	hard	purple
2400	10.9	10.1	hard	purple

Remarks: The unusually high dry strength of this clay, together with its ability to withstand fairly high temperatures, suggests that it might be suitable for use as a refractory bond clay. It may also be suitable for common brick, face brick, drain tile, and flower pots; but test brick showed severe lengthwise splitting upon firing. This splitting would prevent successful use of this material unless the defect could be corrected, possibly by blending in other clays. The high maturing temperature would be an additional disadvantage of this material.

Sample RBJ-35

Location: Georgetown County; from ditch at Hawkins Street crossing of railroad track to International Paper Company mill in west edge of Georgetown.

Field description: This material is thought to be representative of the more sandy phases of clay deposits between Georgetown and Ports Creek, a few miles to the west. Georgetown Brick Company formerly made brick from these clays.

Laboratory results:

Dry transverse strength...227 lbs. per sq. inch
Fired transverse strength..90 lbs. per sq. inch

Temp. (°F)	*Total linear shrinkage (%)*	*Absorption (%)*	*Hardness*	*Color*
2000	6.3	19.5	soft	red
2200	6.3	17.7	soft	red
2400	6.3	16.7	soft	red

Remarks: Because of its high quartz sand content and consequent weakness, this material is not recommended for use in structural products.

Sample RBJ-36

Location: Georgetown County; on dirt road 1.7 miles west-northwest of Waverly Mills; 9.0 miles northeast of Georgetown.

Field description: Sample is from the 20 to 35 foot depth range in Division of Geology auger hole Georgetown no. 5. This material is bluish-gray to black clay or marl of Miocene to Pleistocene age. It is sandy in places and contains sparse to moderate amounts of shell fragments. It is non-calcareous in the upper portion but becomes slightly to moderately calcareous with depth. This unit is very widespread beneath 0 to 40 feet or so of sand in eastern Georgetown County.

Laboratory results:

Dry transverse strength...1005 lbs. per sq. inch
Drying shrinkage.........8.8% linear
Water of plasticity........38.5%
Fired transverse strength..1130 lbs. per sq. inch

Temp. (°F)	*Total linear shrinkage (%)*	*Absorption (%)*	*Hardness*	*Color*
2000	12.0	16.3	soft	salmon
2100	15.8	11.1	hard	brown
2200	melted	....	....	....

Remarks: This material crushed easily and showed high plasticity. It extruded very nicely and formed bars with good plastic strength. Dry strength was unusually high. Drying shrinkage was high, and the tests indicated that this material would give considerable trouble during drying. The sample showed a very narrow vitrification range. It was still quite porous when fired to 2100°F but melted completely at 2200°F.

This material would probably not be desirable as the sole constituent of structural products. It might be used, however, as an additive to clays of low plasticity to improve their plastic qualities. It might also be suitable as the bond clay for limestone in the manufacture of limestone brick. The market potential for this product in the United States is questionable, but such units are made and sold in Cuba and Hawaii. In making this brick, limestone and clay are mixed and fired to about 1100°F. A structural unit of excellent dimensional stability results.

Sample RBJ-37

Location: Williamsburg County; on S. C. 42 about 0.4 mile west of Rhems; about 22.5 miles east of Kingstree.

Field description: Sample is from 5 foot thick bed present within 5 feet of surface over much of the area around Rhems. Probably a Pleistocene marine deposit.

Laboratory results:

Dry transverse strength...1110 lbs. per sq. inch
Extrusion strength ....10¼ inches
Drying shrinkage.........6.9% linear, 29.4% volume
Dry bulk density ....1.97 gms./cc.
Apparent porosity........26.3%
Water of plasticity........34.6%
Shrinkage water 21.1%
Pore water 13.5%
Fired transverse strength..4480 lbs. per sq. inch

Temp. (°F)	*Total linear shrinkage (%)*	*Absorption (%)*	*Bulk density (gms./cc.)*	*Hardness*	*Color*
1950	13.5	8.6	....	hard	pink
2000	13.4	6.0	2.23	hard	red
2100	13.6	5.9	2.22	hard	red
2150	13.2	5.4	2.23	hard	red
2200	13.4	4.7	2.25	hard	red
2250	13.6	4.2	2.27	hard	purple
2300	13.8	3.9	2.32	hard	dark-brown

Remarks: This material displayed an extremely high dry strength, an extremely high fired strength, a very long vitrification range, and a low maturing temperature. These properties of excellence were offset by a high shrinkage and severe lamination of the material. The development of lamination cracks during firing was so severe that strength determinations could be made on only one out of five test bars.

The cracking, high shrinkage, and lamination would prevent use of this material for most structural clay products. However, its other features are so desirable that it may be advantageous to correct the defects of this clay, either through use of electrolytes or by mixing in other materials with different properties.

Sample RBJ-38

Location: Williamsburg County; on S. C. 41 about 1.5 miles north of Rhems; about 23 miles east of Kingstree.

Field description: Sample is from road cut exposure of clay underlying 1 foot of silty soil. Similar material is thought to be present over several square miles in this area. Probably a Pleistocene marine deposit.

Laboratory results:

Dry transverse strength...1210 lbs. per sq. inch
Extrusion strength ....9¾ inches
Drying shrinkage.........8.2% linear, 29.4% volume
Dry bulk density ....2.08 gms./cc.
Apparent porosity........22.5%
Shrinkage water 20.0%
Pore water 11.3%
Water of plasticity........31.3%
Fired transverse strength..3176 lbs. per sq. inch

Temp. (°F)	*Total linear shrinkage (%)*	*Absorption (%)*	*Bulk density (gms./cc.)*	*Hardness*	*Color*
2000	12.4	10.3	2.09	soft	orange-red
2100	12.2	10.6	2.08	soft	orange-red
2150	12.6	10.0	2.09	hard	orange-red
2200	13.6	10.0	2.10	hard	orange-red
2250	12.6	9.6	2.12	hard	red
2300	13.0	9.2	2.24	hard	purple-red

Remarks: This material is very similar to RBJ-39 and could be used in the manufacture of common brick, face brick, drain tile, and possibly structural tile. Dry and fired strengths were very high. Fired specimens developed attractive colors and were free from cracks. The fairly constant shrinkage throughout the firing range would aid the production of brick with good uniformity of dimensions.

Disadvantages of this material are its poor drying properties and high drying shrinkage. It cracked badly upon rapid drying and warped to some extent when dried at a slower rate.

Sample RBJ-39

Location: Georgetown County; on S. C. 41 about 2.4 miles north of Rhems; 19 miles north-northwest of Georgetown.

Field description: The sample is representative of material from depths of 1 to 6 feet. It is common over several square miles in this area. Probably a Pleistocene marine deposit.

Laboratory results:

Dry transverse strength...957 lbs. per sq. inch
Extrusion strength ....10 inches
Drying shrinkage.........8.0% linear, 23.0% volume
Dry bulk density ....1.97 gms./cc.
Apparent porosity........25.0%
Water of plasticity........21.7%
Shrinkage water 15.3%
Pore water 6.5%
Fired transverse strength..2900 lbs. per sq. inch

Temp. (°F)	*Total linear shrinkage (%)*	*Absorption (%)*	*Bulk density (gms./cc.)*	*Hardness*	*Color*
2100	10.4	11.3	2.01	soft	salmon
2200	9.4	10.7	2.01	soft	red
2300	10.8	9.9	2.05	hard	red
2350	10.4	9.5	2.05	hard	red
2400	11.2	8.4	2.02	hard	purple

Remarks: This is a good raw material for common brick, face brick, drain tile, pottery, and possibly structural tile. Dry and fired strengths were very high. Fired samples had pleasing colors and a smooth texture that was free from flaws.

Disadvantages of this material were high drying shrinkage and the high firing temperature needed to produce a hard brick The sample cracked badly during the rapid drying treatment and warped appreciably under slower drying.

Sample RBJ-40

Location: Horry County; O. E. Nixon farm; on U. S. 378 about 2.5 miles west of Conway.

Field description: Sample is composite from ditch bank and auger hole and represents a 4 foot thick bed of buff clay that extends over a square mile or more in this area. The buff clay is overlain by less than a foot of sandy soil and is underlain by a bed of bluish-gray sandy clay 20 feet or more in thickness.

Laboratory results:

Dry transverse strength...675 lbs. per sq. inch
Extrusion strength ....9¼ inches
Drying shrinkage..........6.0% linear, 18.3% volume
Dry bulk density ....2.01 gms./cc.
Apparent porosity........24.4%
Water of plasticity........18.2%
Shrinkage water 11.2%
Pore water 7.1%
Fired transverse strength..1303 lbs. per sq. inch

Temp. (°F)	*Total linear shrinkage (%)*	*Absorption (%)*	*Bulk density (gms./cc.)*	*Hardness*	*Color*
2100	8.0	13.1	1.95	soft	salmon
2200	7.0	12.7	1.96	soft	salmon
2300	8.0	12.5	1.95	soft	red
2400	7.0	11.8	1.94	hard	yellow over purple-gray

Remarks: This clay could be used for the manufacture of light-hard common brick when fired between 2000 and 2200°F. It might also be of interest as a raw material for face brick because of its development of unusual and interesting colors at high firing temperatures.

The quantity of quartz sand in this material greatly detracts from its value. Though not present in large enough amounts to cause the brick to be punky and friable, the sand content does contribute to the high maturing temperature and causes some expansion of the brick during firing.

RBJ-40 could not withstand rapid drying but dried satisfactorily under a slow drying schedule.

Sample RBJ-41

Location: Horry County; 2.0 miles west of Myrtle Beach; just north of U. S. 501 at bridge over Intracoastal Waterway.

Field description: Sample represents 8 foot thick bed of buff and gray, plastic silty clay overlain by approximately 1 foot of silty soil.

Laboratory results:

Dry transverse strength...1108 lbs. per sq. inch
Extrusion strength ....8¼ inches
Drying shrinkage.........5.6% linear, 21.0% volume
Dry bulk density ....2.04 gms./cc.
Apparent porosity........17.7%
Water of plasticity........21.3%
Shrinkage water 13.0%
Pore water 8.3%

Temp. (°F)	*Total linear shrinkage (%)*	*Absorption (%)*	*Bulk density (gms./cc.)*	*Hardness*	*Color*
2100	8.4	11.6	2.04	hard	red
2200	7.2	11.2	2.03	hard	red
2300	8.2	9.6	2.07	hard	brown
2400	9.4	7.5	2.11	hard	brown

Remarks: This material had very good extrusion properties and an unusually high dry strength. It produced attractively colored brick which were free from cracks. The fired strength was moderate.

This clay would be suitable for the manufacture of common brick, face brick, and drain tile. Its principal defects are a high drying shrinkage and a troublesome drying behavior.

Sample RBJ-42

Location: Charleston County; about 1.5 miles northwest of Freeman's Store on U. S. 17 at a point about 15 miles northeast of Charleston.

Field description: Sample is thought to be representative of a clay bed present within a foot or so of the surface over many square miles in this area.

Laboratory results:

Dry transverse strength...268 lbs. per sq. inch
Extrusion strength ....2¼ inches
Drying shrinkage..........1.9% linear, 10.4% volume
Dry bulk density ....1.81 gms./cc.
Apparent porosity.........27.2%
Water of plasticity........18.3%
Shrinkage water 6.4%
Pore water 11.8%
Fired transverse strength..466 lbs. per sq. inch

Temp. (°F)	*Total linear shrinkage (%)*	*Absorption (%)*	*Bulk density (gms./cc.)*	*Hardness*	*Color*
2050	0.80	16.2	1.71	soft	orange-red
2100	1.80	18.1	1.71	soft	orange-red
2150	2.60	17.7	1.71	soft	orange-red
2200	2.60	17.6	1.71	soft	red
2250	2.80	17.0	1.72	soft	red

Remarks: This material would be undesirable as the major raw material for structural products because of its high content of quartz sand. The sand caused the material to have very poor extrusion characteristics and prevented the formation of hard brick at a reasonable temperature.

This material might be useful as an admixture for other clays which display a high drying shrinkage, poor drying properties, or excessive lamination.

SUMMARY AND EVALUATION OF RESULTS

Results of these investigations indicate that resources of common clay suitable for use in structural clay products are abundant in the Coastal Plain of South Carolina. The clay deposits sampled in this study are a small fraction of the deposits that exist in the Coastal Plain, but they provide a clear indication of the types of clays that are available. Material suitable for almost any particular structural clay product can be found at one or more places. Several clay deposits have a number of particularly desirable properties and consequently are well suited as a raw material for almost the whole range of structural clay products. In other cases it is obvious that selective mining and blending of materials would be necessary to overcome defects in certain clays.

It is difficult to evaluate conclusively the potential uses of clay from laboratory tests alone because factors other than the properties of the material have important bearing on its usefulness. A perfect clay in the hands of poor management or processed with inadequate machinery will make inferior products. On the other hand, the combination of skillful management and equipment designed to get the best out of a particular clay can make an acceptable product from a very poor raw material. Some materials may make excellent products but may require an excessively expensive manufacturing process. For these reasons, the recommendations given in this report on the usefulness of individual samples should serve only as a guide to the merits of the material tested. Comparison of the ceramic properties of unproven materials with the properties of materials actually used in the manufacture of structural clay products (see figures 1-10) is very helpful in evaluating the unproven materials. Before accepting an unproven material for large scale use, however, the clay deposit should be thoroughly sampled, and extensive laboratory and plant tests should be made.

Tables 8 and 9 are attempts to classify the materials tested in this study according to properties and suitability for use in structural clay products. Operating efficiency and product quality of existing and proposed plants might be benefited by the use of these tables as a guide to clays particularly suited to a particular product or having properties desired for an admix to correct defects of other materials.

Table 8.—Classification of Clays According to Properties

Low maturing temperature	Refractory clays	High dry strength	Low drying shrinkage	Low firing shrinkage	Low total shrinkage	High fired strength	Very smooth texture	Buff color
RBJ-1	RBJ-9	RBJ-1	RBJ-2	RBJ-9	RBJ-9	RBJ-6	RBJ-8	RBJ-10
RBJ-3	RBJ-10	RBJ-2	RBJ-9	RBJ-10	RBJ-10	RBJ-19	RBJ-26	RBJ-11
RBJ-6	RBJ-11	RBJ-3	RBJ-10	RBJ-11	RBJ-12	RBJ-22	RBJ-30	RBJ-12
RBJ-16	RBJ-12	RBJ-6	RBJ-11	RBJ-12	RBJ-13	RBJ-28		RBJ-13
RBJ-19	RBJ-13	RBJ-7	RBJ-12	RBJ-13	RBJ-14	RBJ-29		RBJ-14
RBJ-22	RBJ-14	RBJ-10	RBJ-13	RBJ-15	RBJ-15	RBJ-30		RBJ-15
RBJ-37	RBJ-15	RBJ-19	RBJ-14	RBJ-16	RBJ-16	RBJ-37		
	RBJ-28	RBJ-20	RBJ-15	RBJ-19	RBJ-19	RBJ-38		
	RBJ-31	RBJ-22	RBJ-19	RBJ-26	RBJ-26	RBJ-39		
	RBJ-33	RBJ-23	RBJ-42	RBJ-27	RBJ-40			
	RBJ-34	RBJ-24		RBJ-28	RBJ-42			
	RBJ-38	RBJ-28		RBJ-31				
	RBJ-39	RBJ-29		RBJ-32				
		RBJ-32		RBJ-34				
		RBJ-33		RBJ-37				
		RBJ-34		RBJ-38				
		RBJ-36		RBJ-39				
		RBJ-37		RBJ-40				
		RBJ-38		RBJ-41				
		RBJ-39		RBJ-42				
		RBJ-41						

Table 9.—Classification of Clays According to Potential Use

Brick	Face brick	Drain tile	Hollow Tile	Sewer pipe	Pottery	Paving brick	Floor tile	Roofing tile	Buff brick	Refractory
RBJ-1	RBJ-1	RBJ-1	RBJ-1	RBJ-6	RBJ-1	RBJ-2	RBJ-1	RBJ-1	RBJ-10	RBJ-10
RBJ-2	RBJ-2	RBJ-2	RBJ-2	RBJ-19	RBJ-2	RBJ-6	RBJ-2	RBJ-2	RBJ-11	RBJ-11
RBJ-3	RBJ-3	RBJ-3	RBJ-3	RBJ-22	RBJ-3		RBJ-3	RBJ-3	RBJ-12	RBJ-12
RBJ-4	RBJ-6	RBJ-4	RBJ-5	RBJ-37	RBJ-6		RBJ-6	RBJ-6	RBJ-13	RBJ-13
RBJ-5	RBJ-19	RBJ-5	RBJ-6		RBJ-11		RBJ-16	RBJ-16	RBJ-14	RBJ-14
RBJ-6	RBJ-22	RBJ-6	RBJ-16		RBJ-13		RBJ-19	RBJ-19	RBJ-15	RBJ-28
RBJ-8	RBJ-23	RBJ-16	RBJ-19		RBJ-15		RBJ-22	RBJ-22		RBJ-33
RBJ-16	RBJ-25	RBJ-19	RBJ-22		RBJ-19		RBJ-32	RBJ-32		RBJ-34
RBJ-19	RBJ-26	RBJ-22	RBJ-23		RBJ-22		RBJ-37	RBJ-37		RBJ-38
RBJ-22	RBJ-28	RBJ-23	RBJ-28		RBJ-32					RBJ-39
RBJ-23	RBJ-29	RBJ-26	RBJ-29		RBJ-37					
RBJ-24	RBJ-30	RBJ-28	RBJ-30		RBJ-38					
RBJ-26	RBJ-32	RBJ-29	RBJ-34		RBJ-39					
RBJ-28	RBJ-37	RBJ-32	RBJ-37		RBJ-41					
RBJ-29	RBJ-38	RBJ-33	RBJ-38							
RBJ-30	RBJ-39	RBJ-34	RBJ-39							
RBJ-33	RBJ-40	RBJ-37								
RBJ-34		RBJ-38								
RBJ-38		RBJ-39								
RBJ-39		RBJ-41								
RBJ-41										

In addition to grouping the various clay samples according to similarity in properties and usefulness, the samples might also be classified as marl, kaolin, bentonite, or alluvial clay.

The characteristics of marl are illustrated by sample RBJ-36. Typically this kind of material has a short firing range because of the presence of a relatively large amount of calcium carbonate.

The characteristics of impure kaolin clays are illustrated by sample RBJ-11. These materials typically exhibit refractoriness, low dry strength, and white to tan fired colors.

Sample RBJ-20 is typical of bentonitic clays. Characteristically these exhibit very high dry strength, extremely high drying shrinkage, very difficult drying behavior, and a pronounced tendency to bloat during firing.

The alluvial clays behave like ordinary brick clays and commonly are distinguished by their lack of extreme values for any given property.

Variation in the properties of samples within a given clay type is very commonly caused by variation in the sand content of the sample rather than in the quality of the actual clay present. It is thought that both the quantity and the particle size of the sand are the major causes of variation in sample properties. These factors should be examined carefully as a possible cause of serious variations in quality of material within a single deposit as well as between different deposits.

Table 10 shows the amount and particle size distribution of the sand in selected Coastal Plain clays. The quantity of plus 200 mesh sand varies from 6 percent to 58.6 percent in these samples. The importance of sand size may be seen from a comparison of samples, C, D, and E. Sample D, a clay containing 21.7 percent sand, exhibited excellent ceramic properties. Only 5.9 percent of the sand fraction of sample D was plus 48 mesh. About 50.3 percent was minus 48 plus 100 mesh, and 43.7 percent was minus 100 mesh. The clay represented by sample C contained 28 percent sand but showed bad surface cracking after firing. The important difference between the two samples seems to be that 42.6 percent of the sand in sample C is plus 48 mesh in size as compared with 5.9 percent for the plus 48 mesh material in the sand in sample D. This coarse sand contributes to the cracking.

Table 10.—Size Analysis of Sand Fraction of Clay Samples

Sample	*Weight Percent Retained on Different Sieves*						*Total percent of + 200 mesh sand*
	10	*20*	*48*	*65*	*100*	*Pan*	
A	0	0	8.9	34.8	....	56.3	58.6
B	0	2.2	27.4	22.4	....	48.0	52.8
C	.1	.7	41.8	9.1	15.8	32.5	28.0
D	0	.8	5.1	28.0	22.3	43.7	21.7
E	0	.9	5.1	2.2	12.0	79.8	30.0
F	....	....	....	....	....	....	6.0

Sample E contained 30 percent sand, but 79.8 percent of the sand fraction is minus 100 mesh. This large quantity of very fine sand is highly effective in diluting the plasticity of the clay and causes this material to have poor extrusion qualities. It would seem that greater quantities of sand can be tolerated when the size of the sand is largely minus 48 plus 100 mesh.

Tests were made on sample RBJ-18 to demonstrate further the influence of sand. All of the plus 200 mesh sand was removed from a portion of this material, and test bars were pressed from the remaining clay containing sufficient water to make it plastic. There was not enough of this material to permit extrusion, but other properties were determined and are shown below:

	Before Washing	*After Washing*
Dry transverse strength	320 lbs./sq. in.	582 lbs./sq. in.
Drying shrinkage	8.6% linear	2.36% linear
Total linear shrinkage (2000° F)	11.4%	15.8%
Fired absorption (2000° F)	17.9%	2.7%
Fired transverse strength (2000° F)	455 lbs./sq. in.	4590 lbs./sq. in.

As can be seen above, the removal of the sand from RBJ-18 almost doubled the dry strength of the material. If it had been possible to extrude the washed clay, it would probably have resulted in an even higher dry strength and certainly in greater drying shrinkage. Perhaps the most significant change resulting from removal of the sand was the ten fold increase in fired strength and the sixfold reduction in absorption at 2000°F. Also, the maturing temperature was reduced by at least 200°F, and the surfaces of fired samples were smooth and free from cracks. This illustrates the importance of sand content in determining the properties and potential uses of clays.

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