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CLAY INVESTIGATIONS IN THE SOUTHERN STATES 1934-35

Reports by

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With an introduction by

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Projects conducted by the Geological Survey under grants
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CHAPTER 1.—INTRODUCTION

By G. R. MANSFIELD

PURPOSE AND SCOPE OF INVESTIGATION

The investigations here described were made by the Federal Geological Survey in 1934 and 1935 under allotments of Public Works funds, as part of a broad program to obtain a better picture than that hitherto available of the character, distribution, and quantity of the mineral resources of the Southern States. It was hoped that the information thus gained might help to establish new industries or extend or otherwise aid those already existing. Investigations of this sort seemed particularly well adapted to the general Public Works program, because they gave employment to both technical and laboring men, they could not be undertaken with the regular appropriations of the Geological Survey, their results were directly for the public benefit, and in the long run they could be expected to pay back to the public directly or indirectly far more than their cost.

The work was necessarily of a reconnaissance nature, because the ground to be covered proved so large that the available funds would not permit the exploration of individual areas or districts in sufficient detail to justify estimates of tonnage of material of different grades. It was possible, however, to eliminate from further consideration much land that gives little promise of supporting commercial development and to direct attention to deposits that it seems worth while to prospect in detail, with the fair chance of finding large bodies of high-grade clays.

TYPES OF CLAY INVESTIGATED

Large deposits of the highest-grade fuller's earth, a type of clay naturally active as a bleaching agent, have long been known to exist in the southeastern United States, notably Florida and Georgia.[1] The clay-mining companies have done intensive prospecting, but their accumulated data have not been published. At present several companies are mining the best and most extensive deposit, and they

[1] Gunter, Herman, and Sellards, E. H., The fuller's earth deposits of Gadsden County, Fla.: Florida Geol. Survey 2d Ann. Rept., pp. 253–291, 1909. McCallie, S. W., A preliminary report on the mineral resources of Georgia: Georgia Geol. Survey Bull. 23, 1910. Shearer, H. K., A report on the baxuite and fuller's earth of the Coastal Plain of Georgia: Georgia Geol. Survey Bull. 31, 1917.

have determined that there are ample quantities available for many years to come.

On the other hand, the only domestic deposits of bentonitic clay now being operated on any considerable scale are in the far southwestern part of the United States. Bentonitic clays or "bentonites" (see p. 8) in the raw state are generally inactive as bleaching agents but are "activable" and become "activated," or acquire bleaching power, when treated with acid. Prior to 1930 little was known of any bentonites east of the Mississippi River except the Ordovician bentonites of Kentucky, Tennessee, and Alabama,[2] which are commercially unimportant. In that year A. C. Trowbridge, in the employ of a private company, discovered a bed of activable bentonite near Laurel, Miss., which proved to be equal to the best imported material.

For several years the Geological Survey, to aid in the search for high-grade deposits, has been making laboratory studies of samples of bentonite received from many parts of the country. Trowbridge's discovery had already directed attention to the Vicksburg group of geologic formations in Mississippi. Commercial operations in fuller's earth at Olmstead, Ill., had also directed attention to the Porters Creek clay, of which the Olmstead deposit is a part. It was therefore decided to study these formations in the field and so far as practicable to follow them and their associates into neighboring States, in the hope that large bodies of high-grade bleaching clays, particularly those of the activable type, might be discovered.

In some States, too, where it was desired to supplement published information or where requests for information relative to special tracts of land had been received, some attention was given to the better grades of ceramic clays. In general lower-grade deposits suitable for brick and tile were so abundant and so well known that no work was done on them.

STATES INCLUDED IN INVESTIGATION

Eight States were included in the investigation—South Carolina, Texas, Kentucky, Tennessee, Alabama, Mississippi, Georgia, and Florida. The States are named in the order in which the respective reports are listed, those by regular members of the Survey's staff being given precedence over those by temporary members. Investigations of bleaching clays were made in each of these States, and ceramic clays were also studied in South Carolina, Texas, Kentucky, Tennessee, and Alabama. The amount of time and money spent was not the same in each State, because at the outset the available information for some States indicated greater promise than that for others. In some States, also, so little had been published on clay resources that larger expenditures seemed justified.

[2] Nelson, W. A., Geol. Soc. America Bull., vol. 33, no. 3, pp. 605–615, September 1922.

DISTRIBUTION OF FUNDS

The total allotment made available to the Geological Survey for the clay studies was $29,000, distributed among the different States as follows: South Carolina, $6,000; Texas, $4,000; Kentucky, $2,000; Tennessee, $2,000; Alabama, $5,000; Mississippi, $5,000; Georgia, $3,000; Florida, $2,000. Conditions of overburden in the areas studied in Kentucky were so unfavorable that little could be accomplished there by the available methods. Much of Kentucky's clay money was therefore diverted to another Public Works project in that State.

METHODS OF FIELD WORK

The field work was directed to certain belts or groups of beds that were known to contain or were suspected of containing bentonitic clays. Outcrops of these beds were sought in stream valleys, gullies, railroad and highway cuts, and at other places. Prospecting was also done at such places and in intervening areas by boring test holes with a 3-inch cup auger of the Iwan Bros. type. Numerous samples were taken at intervals throughout the most promising deposits to determine vertical and lateral variations in quality. These were submitted for testing to the Geological Survey laboratory. For this purpose samples weighing from 1 to 8 ounces each sufficed. Record was kept of the locations of exposures and borings, and sketch maps and profiles were made where necessary.

Work on the ceramic clays was carried on in much the same way, but larger samples weighing 50 to 100 pounds each were necessary to provide sufficient material for the ceramic tests.

BLEACHING CLAY

HISTORICAL SKETCH

The name "fuller's earth" was given to naturally active bleaching clay because of its original use, dating back to Pliny and in England to the Middle Ages, for removing grease and fat from woolen cloth during the process of fulling.

About 1880 N. K. Fairbanks & Co., of Chicago, Ill., learned that in the Orient the color of olive oil was being improved by treating it with clay. They began a series of experiments with cottonseed oil and found that English fuller's earth gave the best results of all clays available at that time.[3]

Fuller's earth was first produced in the United States in 1891, when a bed of Tertiary clay marl near Alexander, Ark.,[4] was opened by John Olsen. This clay was used for a time by the Southern Cotton Oil Co.

[3] Wesson, David, The bleaching of oils with fuller's earth: Min. and Eng. World, vol. 37, p. 667, 1912.

[4] Branner, J. C., An early discovery of fuller's earth in Arkansas: Am. Inst. Min. Eng. Trans., vol. 43, p. 520, 1912.

of Little Rock, Ark., but proved unsatisfactory [5] and the project was short-lived. In 1893 fuller's earth was discovered by accident near Quincy, Fla.[6] During a fruitless effort to burn brick on the property of the Owl Cigar Co. an employee called attention to the close resemblance between the clay being used and German fuller's earth. This discovery caused considerable excitement. Subsequently deposits of supposed fuller's earth were reported from several States, but most of this material proved valueless for use in bleaching.

Florida was the sole domestic producer of fuller's earth on any commercial scale in 1895 and 1896,[7] although small quantities may have been produced elsewhere for local consumption. Colorado and New York became producers in 1897, but the output in both States was small. Utah began production in 1898; Alabama and Massachusetts first reported production in 1904; Georgia, South Carolina, and Texas in 1907; California in 1908; Nevada in 1918; Illinois and Pennsylvania in 1922; Arizona in 1927; Idaho in 1931; Indiana in 1934; and New Jersey in 1935. Some States have produced fuller's earth continuously since their first year of reported production; others have ceased production and have not reappeared as producers; and others ceased production for a period of years but have resumed operations. Most of the present production comes from Georgia and Florida. From 1895 to 1923 Florida produced more fuller's earth than any other State, but in 1924 Georgia took first place. During 1936 the production of fuller's earth in the United States amounted to 230,814 short tons, valued at $2,264,978.

Although bentonite was first described by Knight [8] in 1897 as "taylorite," early reports of the Geological Survey of Canada show that under the name "soap clay" it was already being commonly used at Hudson Bay ports for washing blankets and woolens.[9] The first shipments for commercial purposes were made in 1888 by William Taylor, of Rock Creek, Wyo., after whom the material was at first called "taylorite." Later that name was found to have been preempted, and the clay was then called "bentonite," from its occurrence in the Benton shale of the Rock Creek district.[10] Since 1888 production has grown slowly until in 1936, 291,625 tons [11] was produced by 8 States, of which California and Wyoming were the largest producers, the others being Arizona, Mississippi, Oklahoma, South Dakota, Texas, and Utah.

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[5] Shearer, H. K., Bauxite and fuller's earth of the Coastal Plain of Georgia: Georgia Geol. Survey Bull. 31, p. 142, 1917.

[6] U. S. Geol. Survey Mineral Resources, 1914, pt. 2, p. 36.

[7] U. S. Bur. Mines Minerals Yearbook, 1934, pp. 969–974.

[8] Knight, W. C., Mineral soap: Eng. and Min. Jour., vol. 63, p. 600, 1897; vol. 66, p. 491, 1898.

[9] Spence, H. S., Bentonite: Canada Dept. Mines, Mines Branch, Pub. 626, 35 pp., 1924.

[10] Davis, C. W., and Vacher, H. C., Bentonite; its properties, mining, preparation, and utilization: U. S. Bur. Mines Tech. Paper 438, p. 51, 1928.

[11] U. S. Bur. Mines, Minerals Yearbook, Review of 1936, p. 1261, 1937. The figure given includes 95,043 tons of "rotary mud" credited to California.

The early history of acid-treated clays is somewhat vague. It has been stated [12] that the activation of clay by treatment with either concentrated or dilute acids has been practiced for many years in Europe, and that the firm of Smith & Field, of London, has been using artificial silicates for decolorizing since 1873. Germany has long exported activated bleaching clays to the United States. The period between 1920 and 1925 probably marks the beginning of commercial production of acid-treated clays here. The domestic production was pioneered by the Standard Oil Co. of California and the Filtrol Co., both working in California. Commercially activable clay is practically all bentonitic.

USES

The early uses of naturally active clay for scouring and cleansing long ago ceased to be important. Over 90 percent of all fuller's earth produced in the United States in 1936 was used in decolorizing mineral oils; 5 to 7 percent was employed in treating vegetable oils and animal fats; and less than 1 percent was utilized for miscellaneous purposes.[13]

The activated clays find their principal application also in the refining of mineral and vegetable oils and animal fats. This type of bleaching clay is especially important where strong bleaching power is required, as certain of the better activable clays show a bleaching efficiency three to five times greater than that of the average commercial, naturally active clay.

The uses of bentonite aside from bleaching are probably numerous but are largely still to be determined by experiment. The subject is discussed at some length by Davis and Vacher [14] and by Spence and Light.[15] The last two authors give a list of about 240 patents and a bibliography. Spence's earlier paper [16] also includes a bibliography.

Bentonite has been used increasingly in the foundry industry, and most of the swelling type, obtained chiefly from Wyoming, is believed to be used in this way. Its principal function is as a bonding ingredient to increase the strength of molding and core sands, and it is also used as a suspending agent in core and mold washes. Bentonite is believed to improve the workability and flow of concrete, to prevent segregation before setting and make the finished product waterproof. This use probably ranks next in importance after oil refining and foundry work. De-inking of newsprint, which some years ago gave promise of becoming an important industry and for which bentonite

[12] Bierce, H. E., Some historical notes on the origin of contact filtration: Nat. Petroleum News, Dec. 14, 1927, p. 102.

[13] U. S. Bur. Mines Minerals Yearbook, 1936, p. 1261, 1937.

[14] Davis, C. W., and Vacher, H. C., op. cit.

[15] Spence, H. S., and Light, Margaret, Possible industrial applications for bentonite: Canada Dept. Mines, Mines Branch, Investigations of mineral resources and of the mining industry, 1930, no. 723 II, pp. 12–34, 1931.

[16] Spence, H. S., Bentonite: Canada, Dept. Mines, Mines Branch, Pub. 626, 1924.

seemed adapted, has apparently not developed on the expected scale. Other minor uses, which perhaps deserve mention, are as an improving bonding medium in firebrick and other refractories; in muds in rotary well drilling; in aqueous emulsions; in dispersions of oil, bitumens, etc., in soaps and detergents, sprays, and insecticides; in road, roofing, and floor materials; in cosmetics, polishes, adhesives, ceramic glazes, absorbents, etc.

PRESENT SOURCES OF SUPPLY

Practically all the granulated fuller's earth now used comes from the region around Attapulgus, Ga., and Quincy, Ocala, and Midway, Fla., as no other large deposits have been found of material firm enough to be granulated and burned for re-use without rapid disintegration. The fines are rejected. Fine-ground fuller's earth is mined and ground chiefly near Macon, Ga., and Olmstead, Ill., the Macon product being used largely for bleaching cotton and palm oils, and the Olmstead product for petroleum. Activated clay is produced chiefly at El Segundo and Los Angeles, Calif., and at Port Arthur, Tex. The El Segundo plant obtains its bentonite from Otay, south of San Diego; the Los Angeles plant from northeastern Arizona; and the Port Arthur plant from Riverside, Tex. Lesser amounts mined near Woodward, Okla., and Booneville, Miss., are treated and used as mud ("pulp process") by refiners.

Nutting's investigations at the Geological Survey of a wide variety of natural minerals and synthetics and a variety of treatments [17] have indicated (1) that there are no minerals already in production that appreciably exceed the fuller's earths and activated bentonites in bleaching power; (2) that all the best clays of either class are substantially equal in bleaching power within their respective classes, differing as little from one another as the usual variations through each deposit, (3) that no known synthetic materials or chemical processes can compete with the clays being used in either efficiency or cost, (4) that no treating processes excel those already in use, and (5) that both the activation of clays by acid treatment and the "contact" process of use in decolorizing oils are very old and well known. Attention is therefore centered here on natural resources in fuller's earths and bentonites, their quality, tonnage, and availability.

From available information apparently few deposits of bleaching clays of any consequence occur in the United States north of latitude 38° (Salt Lake, St. Louis, Richmond). The large markets are in the Northeast, the Midcontinent area, and California. The Georgia-Florida area has ample supplies of fuller's earth, and seemingly large supplies of activable bentonitic clay of the highest grade have recently been discovered in northwestern Florida and south-central Mississippi.

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[17] Nutting, P. G., Technical basis of bleaching-clay industry: Am. Assoc. Petroleum Geologists Bull., vol. 19, pp. 1043–1052, July, 1935.

It is hoped that a systematic search may be made of the Southwest, comparable with that here discussed for the Southeast. Occasional samples sent in for test from Arkansas, Colorado, New Mexico, Utah, and Arizona show that in those States, at least, excellent bentonites exist apparently in large quantities. Unfortunately funds were not available for carrying the investigation into the Midcontinent and Western States named.

NATURE OF BLEACHING ACTION

Although the bleaching clays are produced in considerable quantities by many independent operators, they have received little intensive study, and many of the important factors in relation to origin, occurrence, and ultimate commercial applicability are not well understood. Not much is known of the cause of the decolorizing action (bleaching power) nor of its nature except that it is a selective adsorption of some kind. In this connection Nutting [18] states:

> As the bleaching action [of clay] is essentially a selective adsorption of coloring matter on exposed solid surfaces in contact with the liquid to be decolorized, such surfaces must be the seat of bleaching action.

Nutting's research led him to the conclusion that it is the presence of chemically open bonds or free valencies on clay surfaces that make them selectively adsorbing. In a later paper [19] he wrote:

> The open-bond theory of the bleaching action of active oil sands and bleaching clays by selective adsorption set forth by the writer in previous papers * * * has met every test that has thus far been devised. Clay particles (or oil sand grains) are potential bleaching agents for oil when their surfaces hold H or OH radicles adsorbed in a thin layer. When these are driven off by heating, open bonds are left which select from the oil the darker, more basic constituents. At elevated temperatures (100°–200° C.) dark oil particles directly replace hydrogen and hydroxyl ions without previous drying. Certain clays that are not active because bases such as iron, alumina, and calcium already occupy the surface bonds may be activated by replacing such bases by the hydrogen of an acid. The open-bond hypothesis is fundamental in understanding various details of the behavior of bleaching clays.

In addition to the open bonds the contributing factors conducive to adsorption are platy or cleavable crystalline structure, fineness of grain, and characteristic individual bonding of the atoms within the clay material.

ORIGIN

Several theories have been proposed as to the mode of origin of deposits of naturally active clay. Miser [20] described an occurrence in Arkansas which he concluded was the result of alteration in place

[18] Nutting, P. G., The bleaching clays: U. S. Geol. Survey Circ. 3, p. 11, 1933.

[19] Nutting, P. G., Technical basis of bleaching-clay industry: Am. Assoc. Petroleum Geologists Bull., vol. 19, no. 7, pp. 1043–1052, July 1935.

[20] Miser, H. D., Developed deposits of fuller's earth in Arkansas: U. S. Geol. Survey Bull. 530, p. 210, 1912.

of basaltic dikes that contained a high percentage of ferromagnesian minerals.

It has been said that the fuller's earth of Georgia was deposited as a calcareous clay in shallow waters. Shearer [21] stated:

> The leaching of the calcium carbonate left a large volume of openings, while the silica originally present, together with that deposited from solution, formed a framework strong enough to hold the pores open.

Porter [22] and others have presented arguments favoring an origin of fuller's earth from basic rocks in which augites and hornblendes are the prominent minerals. Porter stated further that "practically all workable deposits of fuller's earth are secondary in origin, having been redeposited in sedimentary series.

The deposits of fuller's earth being mined at Olmstead, Ill., have been interpreted by Grim [23] as near-shore marine deposits.

According to Davis and Messer,[24] "the California bleaching earth of the high-magnesia type seems to have been produced by the alteration of a basic crystal tuff that contained some rock fragments."

Grim [25] states that fuller's earth at Ivey, Utah, is a decomposed dacitic breccia underlying conglomerate that is at least in part fluviatile.

Natural leaching has very probably played an influential part, possibly far more influential than has hitherto been suspected, in the development of the various types of bleaching clays. Thus the physical and chemical environment of the clay-forming materials has been most effective in the development of the ultimate product.

The so-called "bentonites" are the most efficient activable clays. It seems well established that the original mineral substance of true bentonites was volcanic ash. Bentonite has been defined by Ross and Shannon [26] as being "a rock composed essentially of crystalline clay-like mineral formed by devitrification and the accompanying chemical alteration of a glassy igneous material, usually tuff or volcanic ash; and it often contains variable proportions of accessory crystal grains that were originally phenocrysts in the volcanic glass." The term "bentonite" has sometimes been applied to clays not known to be volcanic in origin, but for the purposes of this report the definition of Ross and Shannon is followed.

Apparently the sedimentary materials that now make up the bleaching clays were transported to their ultimate sites of deposition either

[21] Shearer, H. K., Bauxite and fuller's earth of the Coastal Plain of Georgia: Georgia Geol. Survey Bull. 31, p. 310, 1917.

[22] Porter, J. T., Clays and clay products: U. S. Geol. Survey Bull. 315, p. 268, 1907.

[23] Grim, R. E., Petrography of the fuller's earth deposits, Olmstead, Ill.: Econ. Geology, vol. 28, p. 363, 1933.

[24] Davis, C. W., and Messer, L. R., Some properties of fuller's earth and acid-leached earths as oil-refining adsorbents: Am. Inst. Min. Met. Eng. Tech. Pub. 207, p. 5, 1929.

[25] Grim, R. E., op. cit., p. 363.

[26] Ross, C. S., and Shannon, E. V., The minerals of bentonite and related clays and their physical properties: Am. Ceramic Soc. Jour., vol. 9, no. 2, p. 79, 1926.

prior to or after the alteration of the original volcanic ash. The agents of transportation are wind and water, and the most favorable sites of deposition are protected inland basins, shallow lakes, and the shallow relatively undisturbed waters of the continental shore lines. Ash may fall directly into fresh or saline basins and remain in place, or the material may be deposited on unprotected land surfaces and subsequently transported. During transportation there is likely to be contamination by the admixture of nonvolcanic materials, which in general do not have the bleaching properties that are apparently typical of decomposed ash. The transported nonvolcanic materials are likely to be less efficient than ash that has remained at the site of the original deposition.

Recent field study by H. X. Bay, with laboratory investigations by P. G. Nutting, has brought to light evidence which may indicate that the major occurrences of naturally active clay in the Southeastern States have been derived directly from volcanic ash or indirectly from the same source through bentonites. The probable sequence of change in quickly submerged and well-protected ash falls is from ash to normal bentonite. On the other hand, where the ash has been subjected to considerable weathering, washing, and transportation, with dilute plant acids and bacteria perhaps assisting, the probable sequence is from ash to fuller's earth. It is thought that through a process of natural leaching, original ash falls may have been altered into activable clays, which, under proper environmental conditions—when leaching continued—were rendered more and more active until the ultimate naturally active state was reached. Some thick beds of fuller's earth are highly activable (bentonitic?), but not naturally active, at the base. Active clays in general do not show recognizable ash structure, but this structure may have been lost during leaching.

Both Mississippi and Georgia contain all intermediate grades of bleaching clay, from partly leached bentonite having little bleaching power when raw to true fuller's earth, which is naturally active and not subject to further activation by acid leaching. This being so, it might be expected, from the theory proposed here, that thick deposits would commonly grade downward from naturally active clays through less naturally active material into inactive but activable clays at the base—that part subjected to the least natural leaching. This variation in activability is characteristic of certain Georgia deposits. Samples from a 30-foot deposit of clay in the Twiggs clay member of the Barnwell formation, 2¼ miles south of Dry Branch, in Twiggs County (see p. 265), yielded the following bleach ratings (for explanation of symbols used, see p. 14):

Sample	Raw				Acid-treated			
	G	Y	R	B	G	Y	R	B
Top	0.6	0.8	0.9	1.0	0.9	1.3	1.4	1.6
Middle	No bleach				1.0	1.4	1.5	1.7
Base	No bleach				1.1	1.8	1.9	2.0

The upper part of this bed has been so thoroughly leached as to be fairly active in the natural state and is only slightly improved by acid leaching, whereas the middle and lower parts are nonactive until treated with acid. The base (which presumably has been leached least) is the most activable. In outward appearance, however, this bed appears to be essentially uniform from top to bottom.

Some deposits, which probably have been subjected to thorough leaching by natural causes, have gone completely over to the naturally active type. This is exemplified by the occurrence at Attapulgus, Ga., where the clay is not affected by acid leaching and has the same bleaching power both before and after acid treatment. Other beds have apparently been leached to a point where the materials are natural bleaching agents of fairly high grade and still yield a high bleach rating after partial acid leaching—for example, the clay of Vicksburg age in Jackson County, Fla. Still others, such as the Vicksburg bentonite of Mississippi, are inactive in the natural state but highly active after partial acid leaching.

Thus, in the Southeastern States we find all intermediate types of bleaching clay, grading from those that are not naturally active but highly activable, on the one hand, to those that are naturally active but not activable, on the other. The evidence seems to indicate that the active and activable clays have had a common source and that in certain deposits the active clays have been derived from the activable clays by a process of natural leaching.

GENERAL CHARACTER

The bleaching clays are usually very fine grained, but in many deposits they carry an admixture of sand particles and mica. The bentonite in the Vicksburg group in Smith County, Miss., is remarkably free from grit, whereas that from the same group in Wayne County, Miss., is decidedly sandy. The colors are usually light, ranging from white to pale green, but may be pink, tan, brown, gray, dark green, blue, or even black. Freshly opened exposures ordinarily exhibit a waxy or soapy texture and translucence and may be cut into thin shavings, like soap. Many varieties are hard and brittle when dry, but some are soft and crumble or are even plastic. Certain types exhibit conchoidal fracture; others show platy, hackly, or no distinctive fracture. Jointing is common in most beds. Bentonites of the Wyoming type have a strong affinity for water and will absorb 3 times their weight or as much as 10 times their volume of water, with a consequent increase in volume (10 or more times the original.)[27] This "swelling" property is not characteristic of many of the so-called "bentonites" of other regions. The swelling bentonites are in general less activable than the nonswelling types. The activable clays commonly slake in water, but most active clays do not.

Nutting[28] writes:

> Most bentonites (bentonitic clays) are readily changed to fuller's earth in the laboratory by simply treating the ground material (150-mesh) with dilute (1 percent or less) HCl, H_2SO_4, or organic acids; some by alternately drying and moistening with water alone.
>
> After room-drying, lumps of bentonite slake readily in water; lumps of fuller's earth do not, or at most crack into large chips. The activable southern bentonites, on slaking to mud, leave unslaked granules from the size of a pinhead down, easily removed and washed on a 100-mesh sieve. These granules are characteristic of each individual bentonite deposit and are useful for identification. The northern bentonites (Wyoming) swell and gel on slaking and do not contain such granules; no activable bentonite fails to show them. If the granules are ground up, treated, and tested, they commonly show the same bleaching power as the fines; in a few cases they activate to a higher power, never to a lower. The slaked fines of an old room-dried sample sometimes are quite inactivable.
>
> Samples of fuller's earth, on room drying, change very little in bleaching power, usually improving slightly with the dehydration, but bentonites deteriorate rapidly both before and after acid treatment, so that samples room-dried for 2 to 6 months are useless for testing. The bleaching power of even fuller's earth drops to about half its initial value on heating to 160° C. for 2 weeks in air (oxidation). Fresh clay keeps well over water in an air-tight desiccator. * * * The open bonds left by partial dehydration are apparently not very stable and form new associations.

GEOLOGIC DISTRIBUTION IN THE SOUTHERN STATES

At different times in the geologic past volcanic ash has been distributed over wide areas, and it is believed that under favorable conditions finely divided ashy materials have been transported several hundred miles from the points of ejection before coming to rest. This is shown by the wide distribution of the Ordovician bentonite, which is known to extend from Birmingham, Ala., northward to the Georgian Bay region, a distance of about 900 miles, and an approximately equal distance east and west.[29] The linear distribution of the Vicksburg bentonite in the Southeastern States is nearly 300 miles.

If it is granted that the major deposits of bleaching clay (both active and activable) in the Southeastern States have been derived directly or indirectly from volcanic ash, it follows that there have been at

[27] Davis, C. W., and Vacher, H. C., Bentonite, its properties, mining, preparation, and utilization: U. S. Bur. Mines Tech. Paper 438, p. 9, 1928.

[28] Nutting, P. G., Technical basis of bleaching-clay industry: Am. Assoc. Petroleum Geologists Bull., vol. 19, no. 17, pp. 1043–1052, July 1935.

[29] Ross, C. S., personal communication.

least eleven epochs during which volcanic ash was deposited in different parts of that area. These epochs were probably as follows:

Cenozoic:
- Miocene:
  - Hawthorn formation: Thick deposits of fuller's earth in Florida and Georgia.
- Oligocene:
  - Vicksburg group: Bentonite in Mississippi and bentonitic clays in Florida, Georgia, and Alabama (?).
- Eocene:
  - Jackson formation: Probable ash falls shown by two thick beds of bleaching clay which are separated by 50 to 75 feet of sand in the Ocala limestone, of Jackson age, in Georgia; bentonite (?) and bentonitic (?) clay in the Jackson formation of Mississippi; bentonitic (?) clay in the Jackson formation of Alabama.
  - Lisbon formation: Bentonitic (?) clays in Clarke and Choctaw Counties, Ala.
  - Porters Creek clay (Sucarnoochee clay in Ala.): Bleaching properties vary considerably over wide areas—southern Illinois, southeastern Missouri, western Kentucky, western Tennessee, Mississippi, and Alabama. It probably represents a time during which ash was deposited.

Mesozoic:
- Upper Cretaceous:
  - Eutaw formation: Three beds of bentonite, one in each of the three members of the formation, in northeastern Mississippi. The Upper Cretaceous Taylor marl and Navarro formation of Texas contain bentonitic beds which may correspond with some of those in the Eutaw just mentioned.

Paleozoic:
- Ordovician:
  - Chickamauga limestone: Two ash falls giving rise to two beds of bentonite, which are separated by heavy beds of limestone. Present in Chickamauga limestone of northwestern Georgia and northern Alabama and in contemporaneous beds in Kentucky and elsewhere.

RELATION TO VOLCANIC ACTIVITY

Volcanic activity during the Ordovician period is well established in Tennessee, Kentucky, Alabama, and Georgia.[30] Nelson [31] has suggested that the center of activity was located at some point between Fayette and Elliot Counties, Ky.

Much evidence has been given favoring widespread volcanic activity in the Southern States during Upper Cretaceous time. Volcanic

[30] Nelson, W. A., Volcanic-ash beds in the Ordovician of Tennessee, Kentucky, and Alabama: Geol. Soc. America Bull., vol. 33, pp. 605–615, 1922. Butts, Charles, The Paleozoic rocks, in Geology of Alabama: Alabama Geol. Survey Special Rept. 14, pp. 113–114, 131–133, 1926; U. S. Geol. Survey Geol. Atlas, Bessemer-Vandiver folio (no. 221), pp. 7, 16, 1927. Ross, C. S., Miser, H. D., and Stephenson, L. W., Water-laid volcanic rocks of early Upper Cretaceous age in southwestern Arkansas, southeastern Oklahoma, and northeastern Texas: U. S. Geol. Survey Prof. Paper 164, p. 193, 1928. Kay, G. M., Distribution of Ordovician altered volcanic materials and related clays: Geol. Soc. America Bull., vol. 46, no. 2, pp. 225–244, 1935.

[31] Nelson, W. A., op. cit., p. 610.

materials occur in Arkansas,[32] Oklahoma,[33] Louisiana,[34] Texas,[35] Mississippi,[36] and Alabama.[37] Ross, Miser, and Stephenson [38] have described volcanic vents of Cretaceous age in Arkansas, Oklahoma, and Texas, and there are probably others that have been concealed by younger formations. It appears that during Cretaceous time there was an arc of volcanic activity paralleling the shore line of the Gulf of Mexico.

Evidence of volcanic activity during Tertiary time has been reported from Alabama,[39] Louisiana,[40] Texas,[41] and Arkansas.[42]

The discovery of volcanic tuff and agglomerate 65 to 90 miles south of San Antonio, McMullen County, Tex., led Bailey [43] to think that a volcano had been active at no great distance from that locality during the Oligocene epoch. An active volcanic vent in such a location might well have contributed ash to certain of the Southeastern States during middle and late Tertiary time.

Little is known of the locations of the Tertiary volcanoes that gave rise to the several ash falls of that time. It is possible that some of the volcanic vents that bordered the Gulf of Mexico during Cretaceous time again became active during the Tertiary and supplied thick beds of ash to the surrounding country.

LABORATORY PROCEDURE

The method of testing bleaching clays in the U. S. Geological Survey laboratory has been devised by P. G. Nutting, who contributes the following account.

The various methods used in testing clays in different testing laboratories are all simple, but rating them by any fixed general standards seems almost impossible. Each laboratory chooses its own test method, test oil, and reference standard clay. The reference clay changes with age, and neither it nor the test oil can be exactly duplicated. A common method is to mix 2, 4, 8, 16, and 32 percent by weight of prepared clay with the test oil (100 cubic centimeters), heat to a given temperature (100° to 200° C.) for a given time (20 to 40 minutes) with constant stirring, filter

[32] Ross, C. S., Miser, H. D., and Stephenson, L. W., op. cit., pp. 194–196.

[33] Idem, pp. 188–189.

[34] Bramlette, M. N., Bentonite in the Upper Cretaceous of Louisiana: Am. Assoc. Petroleum Geologists Bull., vol. 8, pp. 342–344, 1924.

[35] Ross, C. S., Miser, H. D., and Stephenson, L. W., op. cit., pp. 196-200. Lonsdale, J. T., Igneous rocks of the Balcones fault region of Texas: Texas Univ. Bull. 2744, 1927.

[36] Grim, R. E., Bentonite in Mississippi: Mississippi Geol. Survey Bull. 22, 1928. Morse, H. McD., Supplementary report on bentonite in Mississippi: Mississippi Geol. Survey Bull. 22–A, 1934.

[37] Stephenson, L. W., The Mesozoic rocks, in Geology of Alabama: Alabama Geol. Survey Special Rept. 14, p.236, 1926.

[38] Ross, C. S., Miser, H. D., and Stephenson, L. W., op. cit., pp. 189–191.

[39] Idem, p. 193.

[40] Hanna, M. A., An interesting volcanic ash from Calcasieu Parish, La.: Am. Assoc. Petroleum Geologists Bull., vol. 10, pp. 93–95, 1926.

[41] Bailey, T. L., Extensive volcanic activity in the middle Tertiary of the south Texas Coastal Plain: Science, new ser., vol. 59, pp. 299–300, 1934. Dumble, E. T., A revision of the Texas Tertiary section with reference to oil-well geology of the coast region: Am. Assoc. Petroleum Geologists Bull., vol. 8, pp. 224–244, 1924.

[42] Crider, A. F., Volcanic ash in northern Louisiana: Am. Assoc. Petroleum Geologists Bull., vol. 8, pp. 524–525, 1924.

[43] Bailey, T. L., op. cit., p. 299.

out the clay, and compare the color of the filtered oil with a set of Tagliabue color standards. But stirring is imperfect, oxidation darkens the oil during treatment, and various uncertainties arise. In the Geological Survey laboratory a percolation method is much preferred and a cold crude test oil, (the conventional test being used only for cotton and linseed oils), because of the details of behavior which it reveals.

According to Geological Survey practice the raw clay to be tested is room-dried, ground, and put through a 150-mesh sieve, then put in an oven at 160° C. for an hour. The 150-mesh size (0.1 mm) is fine enough to permit all the clay to bleach, but coarse enough to permit a percolation test to run in about an hour. A temperature of 160° C. is found to be proper to remove moisture (capillary, adsorbed, and osmotic water) from this class of clays without disturbing the internal structure or closing any open bonds. The test of the acid-leached clay is similar except that the 150-mesh clay is cooked for 2 hours in 20 percent HCl or H_2SO_4, then thoroughly washed, dried, and resifted. The amount of dilute acid used is 100 cubic centimeters to about 3 grams of clay. The time and temperature of cooking, acid concentration, and ratio of acid to clay are all important factors.

The clay thus prepared is placed in a 6-inch length of vertical ⅜-inch tubing closed at the bottom by a porous disk of blotting paper.[44] It is then wet with gasoline, stirred thoroughly, and allowed to drain. This treatment avoids channeling, which is likely to occur if the test oil is poured on the dry clay. Next, the black test oil is introduced, slowly at first to avoid disturbing the clay. It comes through water-white at first, then green, yellow, red, and finally black again, as bleaching action ceases. The volume of oil bleached to one of the colors mentioned compared with the volume of clay used gives a ratio for the selected specimen, which represents its bleach rating for the stated color. The bleach ratings given in the tables used in this report comprise groups of ratios of this sort, the colors being indicated by the initials G, Y, R, and B. Allowance is made (0.4–0.6) for the gasoline left in the voids of the clay.

To find the maximum bleaching power of a clay, it is necessary to obtain at least six sets of points on the curves of bleaching power plotted against amount of material removed by the acid.[45] Six 3-gram samples of the 150-mesh raw clays are weighed out and cooked for periods ranging from half an hour to 4 hours in a 5 to 40 percent acid, washed, dried, and weighed again, resifted, oven-dried at 160°, and then given the oil test and the results plotted. In the tables used in this report the bleach ratios given for any clay tested are those for the raw sample and the treated sample that give the highest bleach.

The test oil used in the Geological Survey laboratory is a black Kettleman crude oil of 40.1° gravity, diluted with an equal amount of gasoline. This gives Floridin fuller's earth a rating of 1.0 for water-white bleach and gives the test treated clays nearly an equal amount of green, yellow, and red. The topped and dewaxed residues of Pennsylvania oils give far too much red. Crudes containing more than 0.5 percent of sulphur are unsuited for test oil. Solutions of dyes in benzine have been used for testing clays, but these differ widely from oil in behavior. All the tests given in this report were made with test oil from a large stock on hand and are strictly comparable with one another.

Room drying has little effect on the bleaching power of a fuller's earth except to improve it slightly, but most room-dried bentonites deteriorate rapidly—as much as 30 percent in a month—in both activability (raw) and in bleaching power after acid treatment. An old sample is worthless for test. All the tests here reported were made on samples fresh from the ground.

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[44] Nutting, P. G., Bleaching clays: Oil and Gas Jour., Nov. 16, 1933.

[45] Nutting, P. G., Bleaching clays: Oil and Gas Jour., Jan. 26, 1933.

To illustrate the test data and their significance, those relating to a few typical clays are given below. The "oil bleach raw" and "acid-treated" have been explained above. Under "Acid-soluble" are given the relative amounts of Fe, Al, and Ca leached out by the acid from the clay "treated," with the percentage of the weight of the clay removed during leaching to produce maximum bleaching power. The maximum acid leach is usually about 40 percent. For most bentonites soluble Fe : Al : Ca=5 : 4 : 1.

According to the laboratory practice of the Geological Survey the lowest limits of bleach permissible for clays that may be considered of commercial grade are as follows:

	Green	*Yellow*	*Red*	*Black*
Naturally active clay (raw)	0.7	0.9	1.0	1.2
Activable clay (acid treated)	1.4	2.0	2.4	2.9

[It should be noted, however, that economic conditions in a given area, such as favorable location with respect to markets, cheap transportation, and company ownership, strongly influence commercial standards in that area. Thus a high-grade deposit unfavorably situated may not be commercial, whereas a low-grade deposit, perhaps even of lower grade than that indicated above as the lowest permissible, may be commercial if favorably situated.]

Tests of representative bleaching clays

		Oil bleach raw				Acid-treated				Acid-soluble			
		G	Y	R	B	G	Y	R	B	Fe	Al	Ca	Off (percent)
1	Floridin	1.1	1.2	1.4	1.6	0.9	1.1	1.2	1.4	5	4	1	20
2	Creede	1.0	1.2	1.3	1.5	1.1	1.6	1.9	2.2	5	3	2	20
3	F87	1.3	1.8	1.9	2.0	1.7	2.6	3.4	4.0	9	1	0	25
4	Sanders	.6	.7	.8	.9	1.8	2.7	3.1	3.6	5	4	1	29
5	Laurel	.2	.3	.3	.3	2.1	3.0	3.6	4.2	5	4	1	30
6	P. C	.7	.9	1.0	1.1	.9	1.3	1.4	1.5	6	4	Tr.	25
7	Eng. XL	1.2	1.3	1.3	1.3	2.0	3.7	3.9	4.1	5	4	1	26
8	Wyoming	.4	.5	.5	.5	1.0	1.3	1.5	1.7	5	4	1	19
9	Booneville	.3	.4	.4	.4	1.4	2.0	2.5	2.9	5	4	1	28
10	Ky. Ord	.9	1.2	1.3	1.4	1.6	2.4	3.2	3.7	5	4	1	20

1. Selected Floridin fuller's earth from area north of Quincy, Fla. Average production is somewhat lower in bleach—about 1.0 to 1.3 raw, and 0.7 to 1.0 acid-leached. Attapulgus clay tests the same. Note that the bleach is lowered by acid treatment.
2. Creede, Colo.: Fuller's earth as produced by the Peerless Co. The bleaching power of this clay is raised by acid leaching but not sufficiently to pay the added cost.
3. F87, an extreme type recently discovered near Marianna, Fla. A first-class fuller's earth and activable bentonite as well. The high iron is noteworthy.
4. Sanders, Ariz.: The white bentonite mined by the Filtrol Co. in northeastern Arizona and treated in Los Angeles.
5. Laurel, Smith County, Miss.: Vicksburg bentonite with low bleach raw and the highest known after proper acid leach.
6. Porters Creek: Average sample showing the typical behavior of a bentonite mixed with inert sedimentary clay. About the lower commercial limit in bleaching power for fuller's earth.
7. English imported fuller's earth: The yellow bleach of the treated sample is the highest known, but the red separation is poor (stale sample).
8. Wyoming swelling bentonite: Useless as a bleach clay.
9. Booneville, Miss.: Cretaceous (Eutaw) bentonite. Taken as the lower limit (in bleaching power) of commercial interest.
10. Ky. Ord.: The lower Ordovician bed at High Bridge, Ky. Note similarity to younger bentonites.

CERAMIC CLAY

TYPES AND GEOLOGIC RELATIONS OF DEPOSITS

The deposits of ceramic clay that are described in this report are included in or associated with rocks that range in age from early Paleozoic to Pliocene. If classified according to origin, the deposits fall into two groups—clays that form an integral and original part of the geologic formation with which they are associated and clays that have accumulated later by the disintegration or weathering of deposits not originally clay. It therefore does not necessarily follow that all the clay deposits are of the same age as the formations to which they are assigned. Some of them may even be of Recent origin.

The oldest rocks with which this report deals are the dolomites (magnesian limestones) of Cambrian or Ordovician age. In Talladega and De Kalb Counties, Ala., these dolomites contain pockets of residual clay that lie at or near the surface and may still be in the process of accumulating.

Deposits of ceramic clay are interbedded with the Fort Payne chert, of Mississippian (late Paleozoic) age, in De Kalb County, Ala. Other deposits of ceramic clay mark a post-Paleozoic land surface that underlies the Tuscaloosa formation (basal Upper Cretaceous) of Marion County, Ala., and are regarded by Bramlette (p. 209) as residual from underlying formations of Pennsylvanian age (late Paleozoic).

The Tuscaloosa formation, at the base of the Mesozoic of the Southeastern States, includes valuable deposits of sedimentary kaolin and other ceramic clays that are now being worked in Georgia and South Carolina.

The Cenozoic formations contain clay deposits at many different horizons. Eocene, Oligocene, Miocene, and Pliocene clays were examined in preparation for this report. Among the Eocene formations that contain ceramic clay may be mentioned the Wills Point formation (of upper Midway age), the Indio formation (of Wilcox age), and the Carrizo sand and Yegua formation (of Claiborne age) of Texas and the Holly Springs sand (of Wilcox age) of Tennessee.

The widely distributed Pliocene Citronelle formation contains lenses of white sedimentary kaolin.

LABORATORY TESTS

The samples of ceramic clay collected for testing in Kentucky, Tennessee, and Alabama were tested in the laboratories of the School of Chemistry, Metallurgy, and Ceramics of the University of Alabama under the direction of Prof. T. N. McVay. He has kindly supplied the following outline of procedure, which conforms, in general, with methods adopted as standard or tentative standard by the American Ceramic Society.[46]

The South Carolina samples were tested at the ceramic laboratory of the Georgia School of Technology under the direction of Dr. A. V. Henry, and those from Texas in the Bureau of Industrial Chemistry of the University of Texas under the direction of Dr. E. P. Schoch. The methods employed were similar to those cited for Alabama and need not be given here in detail.

[46] The standards report for the American Ceramic Society: Ceramic Soc., Jour., vol. 11, no. 6, June 1928.

Screen tests.—Screen tests were made by washing samples of ground clay through Tyler standard screens of 115-, 150-, and 200-mesh. Washing was continued until no particles of clay substance could be seen on the screens. The sieves were then dried at 110° C., and, after shaking, the residues on each screen were weighed and the percentage of oversize calculated.

Modulus of rupture.—Tests to determine the modulus of rupture were made only on those samples that showed some promise of having bonding properties. The clay was ground to pass a 10-mesh sieve, and a sample was dried at 110° C. in order to obtain the moisture content. The clay (corrected for moisture content) was mixed with 150-mesh potter's flint, thoroughly blunged with water in a bucket, screened through a 115-mesh screen and placed in cloth-covered plaster of paris bats to dry to the proper working consistency. After the correct water content was obtained as noted by the satisfactory working properties, the clay was thoroughly wedged and stored in damp jars for 24 hours. A piece of the plastic body was then cut from the lump, placed in the mold, and firmly pressed into shape. Excess clay was struck off with a spatula. The molds were 7 inches in length and 1 square inch in cross section. The bars were dried according to the standard procedure.

The bars were broken by allowing a stream of water to flow into a bucket which was fastened to a stirrup fitted over the test piece. All bearing surfaces had a radius of a quarter of an inch. After failure occurred the bucket, stirrup, and water were weighed. With a few clays that had a very high breaking strength it was necessary to weight the bucket with several bricks before the stream of water was allowed to flow into it. The dimensions of the test pieces were taken at the point of failure, and the modulus of rupture was computed from the formula $\frac{3\,Wl}{2bd^2}$, in which W is equal to the load in pounds, l the distance between supports in inches (in these tests, 5 inches), b the breadth of the bar in inches, and d the depth of the bar in inches. In order to have comparative results, similar tests were made of two well-known ball clays. These were Kentucky Old Mine ball clay no. 4, which had a modulus of rupture of 332 pounds to the square inch, and Special Tennessee ball clay no. 1, which had a modulus of rupture of 155 pounds to the square inch. Potter's flint was used instead of standard sand, because it is the usual practice to use potter's flint with ball clays in order to make ceramic bodies. Standard sand with round grains is never used in commercial ceramic mixes.

Water of plasticity, shrinkage water, and pore water.—The percentage of water of plasticity was determined by the formula $\frac{P-D}{D}\times 100$, in which P equals the weight of the test bars in the plastic state and D

equals the weight of the bars dried at 110° C. The shrinkage water is the water lost during the shrinkage of the clay in drying and is equal to $\frac{Vp-Vd}{D}\times 100$, in which Vp is equal to the volume of the plastic test bar and Vd is equal to the volume of the bar after drying. The percentage of pore water can be determined from the following formula: Percentage of water of plasticity=percentage of shrinkage water+percentage of pore water.

Forming of clay bars.—The clay used for the drying and firing tests was ground, wedged with the addition of the proper amount of water (this is best determined by practice), stored in damp jars for 24 hours, and then molded in iron molds 6 inches in length and 1 square inch in cross section. These bars were then cut in half, the corners smoothed with the fingers, the plastic volumes of some of them were determined, and all of them were dried at room temperature. All volumes were determined by the suspended weight method using kerosene as the liquid. This method has been found to be more accurate than the usual method using over-flow volumeters.

Firing.—The bars were fired in a gas-fired test kiln at the rates prescribed by standard practice.[47]

The range of cones used shall cover the firing range of the clay, which must be judged by the operator. Generally, the cones to be placed in the kiln are 014 to 3 for impure, common brick clays, 012½ to 5 for shales and the better types of ferruginous clay, and 02 to 15 for clays of the fireclay type. Oxidizing conditions must be maintained during firing.

The heating shall preferably be at the rate of 45° C. per hour from the start of firing until a heat treatment is reached, corresponding to the softening point of the third consecutive cone below that at which the first trial is to be drawn; and 20° C. per hour from that point until the end of firing. In no case shall the rate of heating be greater than 60° C. per hour or less than 30° C. per hour for the first period, or greater than 25° C. per hour or less than 15° C. per hour for the last period.

The end points of pyrometric cones (heated in air) at a rate of 20° C. per hour are as follows:

Cone	Temperature (° C.)	Cone	Temperature (° C.)
06	1, 005	6	1, 190
05	1, 030	7	1, 210
04	1, 050	8	1, 225
03	1, 080	9	1, 250
02	1, 095	10	1, 260
01	1, 110	11	1, 285
1	1, 125	12	1, 310
2	1, 135	13	1, 350
3	1, 145	14	1, 390
4	1, 165	15	1, 410
5	1, 180		

[47] Idem, p. 455.

Draw trials were made at the different cones, since there were not enough samples to warrant an individual firing for each cone temperature.

Fusion point.—Fusion points (pyrometric cone equivalent, or P. C. E.)[48] were determined in a standard furnace which was developed by the Mellon Institute, Pittsburgh, Pa., using natural gas as the fuel. The temperatures corresponding to such P. C. E. are as follows:

Cone	End point (° C.)	Cone	End point (° C.)
26	1,595	32	1,700
27	1,605	32½ (approximately)	1,722
28	1,615	33	1,745
29	1,640	34	1,760
30	1,650	35	1,785
31	1,680	36	1,810

SUMMARY OF RESULTS

BLEACHING CLAYS

The clay of the Porters Creek formation (Sucarnoochee in Alabama), of Eocene age, is mined commercially at Olmstead, Ill., and used for bleaching petroleum oils. This formation extends southward and southeastward through western Kentucky and Tennessee into northeastern Mississippi and northwestern Alabama. Its outcrop through these States was studied, sampled, and tested, with the result that in Kentucky and Tennessee three general areas were found (one in Kentucky and two in Tennessee) in which material of quality generally comparable to that mined in Illinois is present in considerable abundance. It is fuller's earth of generally poorer quality than that of Georgia or Florida. Its utilization will depend on its relative cheapness and its proximity to markets or centers of consumption. The Tennessee and Kentucky material is not very favorably located in this respect. The extensions of the Porters Creek formation into Mississippi and Alabama contain poorer material than the deposits in Tennessee and Kentucky and are more remote from markets.

In Mississippi bleaching clay of the activable type is found in the Eutaw formation, of Upper Cretaceous age, which crops out in the northeastern part of the State and has been mined at Booneville, in Prentiss County. Other deposits of activable clay occur in the Jackson formation, of Eocene age, and in the Vicksburg group, of Oligocene age. These formations crop out in belts extending approximately from northwest to southeast across the southern part of the State. In general, the clays of Jackson age are of poorer quality than those of the Vicksburg group. The best material found in Mississippi and, in fact, throughout all areas investigated is that of Vicksburg age at certain localities in Smith County, Miss.

[48] Am. Soc. Testing Materials, Standards on refractory materials, February 1934, p. 54.

The clays of Eutaw, Jackson, and Vicksburg age extend eastward into Alabama, but the results of their investigation in that State were disappointing. Some clays found would justify further investigation, though none of these were of exceptional quality. The best material was clay of Eutaw age in a locality northeast of Montgomery, in Montgomery County, but unfortunately the available supply is too small to be of commercial interest.

The fuller's earth mined in Decatur County, Ga., comes from the Hawthorn formation, of Miocene age, is a leading world source of supply, and occurs in great abundance. That produced in Twiggs and Wilkinson Counties comes from the Barnwell formation, of Eocene age. Some of this is activable as well as naturally active, but most of the activable material from this source is not sufficiently so to be of commercial interest. Bentonites of Ordovician age are present in four counties in the northwestern part of Georgia but are of inferior quality, difficultly minable, and therefore not of commercial interest. Some activable clays in the Flint River formation (Oligocene) in Crisp, Dougherty, Dooly, Macon, Sumter, and possibly other counties approach commercial requirements and deserve further study. The Hawthorn formation, besides yielding so much fuller's earth, contains activable clays of high quality. Those of Brooks and Colquitt Counties deserve further study.

Investigations in South Carolina failed to reveal any extensive deposits of high-grade bleaching clay.

Florida, like Georgia, contains extensive deposits of fuller's earth which are being exploited on a considerable scale. It was formerly the leading producing State. The fuller's earth is of Hawthorn (Miocene) age and occurs in Alachua, Gadsden, Jackson, Jefferson, and Marion Counties. High-grade activable clays, hitherto unrecognized, were found apparently in considerable quantities in Holmes, Jackson, Washington, Leon, and Jefferson Counties. Some of these were of Vicksburg (Oligocene) age and some of Hawthorn age. This discovery was one of the high points of the investigation and promises to be of considerable commercial importance to the State.

In Texas bleaching clays are present in the Taylor marl (Upper Cretaceous) in Bexar County, the Jackson formation (Eocene) in Grimes, Burleson, Fayette, Gonzales, and Karnes Counties, and the Catahoula formation (Miocene) in Walker County. Minor occurrences have been noted in the Anacacho and Navarro formations (Upper Cretaceous) and in the Midway and Wilcox (Eocene) of Bexar County and the Carrizo (Eocene) of Atascosa County. Production from the Taylor formation in Bexar County has ceased, but production is now in progress from the Jackson formation in Burleson, Fayette, and Gonzales Counties and from the Catahoula formation in Walker County. These clays have generally lower bleaching power than those in the

States above mentioned. Lower quality, however, is offset at least in part by proximity to market and correspondingly lower freight rates.

CERAMIC CLAYS

South Carolina kaolin was apparently first used in pottery, plates, bricks, pipes, insulators, etc. Later it was widely used for paper filler. More recently it has become the basis of a growing business in connection with the rubber industry. The present investigation was concerned chiefly with sedimentary kaolins of the Tuscaloosa formation (Upper Cretaceous) and with some residual clays of the Piedmont area. The clays of the Tuscaloosa, which are lenticular, are thicker and of better quality in the western part of the State, and the investigation was largely confined to that region, especially Aiken County. Some 56 prospecting tests were made, of which half penetrated 5 feet or more of clay, 7 being made in active or abandoned clay pits. Much of the clay exposed by these tests was more or less colored and gritty. At least two gave promise of use in the rubber industry. Of 31 samples collected for ceramic tests from pits and outcrops, 8 gave promise of satisfactory use in white-ware industries, and 9 more yielded fair ratings.

In Texas the ceramic-clay investigations were confined to two areas—a group of counties surrounding San Antonio, and Morris County, in northeastern Texas. No deposits of clay of unusually high quality or of special properties were revealed, but information was obtained on the extent of clays suitable for the manufacture of brick, tile, and low-grade pottery. Of the many samples collected 16 from 14 localities in the San Antonio area, were completely tested for their ceramic properties, and 7 of these proved suitable for low-grade pottery: the rest only for brick or admixture with other clays. No clays are now produced in Morris County, but 6 samples were selected for testing, 2 of which came from the adjacent Titus County. The results of the testing showed the clay to be useful chiefly for common brick, but two of the samples indicated that the material represented could probably be used for cheap pottery.

In Kentucky no work was done on ceramic clays, because of the thickness and character of the overburden and the difficulty of obtaining samples by the methods available.

In Tennessee clay lenses in the Holly Springs sand (Eocene) were investigated for ball clays at favorable localities in Hardeman and Carroll Counties. The clay outcrops tested were only small parts of the deposits represented, but these deposits were not more thoroughly tested because most of the results obtained did not appear of sufficient promise to justify additional work. Some of the clay deposits, though not first-grade ball clays, are of value for particular uses and will perhaps be worth development. The results do not disprove the presence of large reserves of good ball clays, for the numerous ball clays already found underneath the cover of gravel and sand make it seem very probable that large deposits yet remain undiscovered. However, the lenticular and sporadic occurrence of the clay in an otherwise sandy formation and the prevalence of considerable cover tend to discourage exploration until industrial needs become more acute.

In Alabama ceramic clays occur in wide variety. Most of the occurrences were examined, and those of greatest promise were prospected, sampled, and tested. In Marion County discontinuous and lenticular bodies of kaolin occur at the Pennsylvanian and Upper Cretaceous contact. The clays include refractory fine-grained material suitable for use as an ingredient in white-ware bodies and refractory brick, together with deposits of more plastic material of possible value as plastic fire clays and pottery clays. In Mobile and Baldwin Counties numerous clay beds suitable for brick clay are exposed. Some Pliocene clays are white sandy sedimentary kaolin, which after washing should be useful as an ingredient of white-ware bodies. In Bibb and Talladega Counties the clays examined include both sedimentary plastic and residual types. The plastic fire clays are in the lower part of the Upper Cretaceous. The residual clays are locally developed on Cambrian and Ordovician dolomites. Both types are pockety, and intensive prospecting would be necessary to develop large tonnages. In De Kalb County residual clays have been extensively worked in the past. The two main modes of occurrence are as residual pockets in the Cambrian and Ordovician dolomites and as seams interbedded with chert of Mississippian age.

ACKNOWLEDGMENTS

The reports that follow this introductory chapter were prepared by the men who did the work in the field. The present writer visited several of the field parties but made no independent contribution to the reports other than to harmonize and adapt them for publication in a single volume. In the preparation of the introductory chapter he has drawn freely on the subject matter of the different reports as submitted and is especially indebted to his colleagues P. G. Nutting, C. Wythe Cooke, and H. X. Bay. L. W. Stephenson spent brief periods in the field with parties in Kentucky, Tennessee, Mississippi, Alabama, and Texas. Similarly C. Wythe Cooke accompanied parties in Mississippi, Alabama, Georgia, Florida, and South Carolina. C. S. Ross and P. G. Nutting visited Cretaceous and Tertiary exposures of bentonitic material in Mississippi and of Ordovician bentonite in Tennessee and Kentucky. Individual acknowledgments are made in the separate chapters.

CHAPTER 2.—THE SEDIMENTARY KAOLINITIC CLAYS OF SOUTH CAROLINA

By WALTER B. LANG

HISTORICAL SKETCH

The kaolins of South Carolina were recognized before the now famous English china clays were known. Natural outcrops of kaolin upon the hillsides and in the ravines must have attracted the attention and excited the curiosity of the earliest pioneers who explored westward across the South Atlantic States. South Carolina kaolin was apparently first used to make pottery. An old pottery works stood upon a ridge 1½ miles south of Bath, in the Horse Creek Valley, Aiken County. Here were molded and fired all manner of crockery and plates, bricks, pipes, and telegraph insulators. This plant was destroyed during Sherman's march to the sea, and material interest in ceramics in South Carolina apparently passed out with it. After a brief lull following the war between the States, the McNamee mine was opened up not more than a mile from the old pottery works. The remarkable purity and whiteness of these clays obtained for them a ready market in paper manufacture. South Carolina thus acquired an enviable reputation for the production of fine clays for paper and for filler in different products. For many years paper manufacturers in the North continued to be the main consumers of South Carolina kaolin until, hardly more than a decade ago, it entered the rubber industry as a substitute for more expensive chemical fillers. The production of South Carolina kaolin for this purpose has steadily grown in late years, and now kaolin for use in rubber manufacture bids fair to become the State's chief crude mineral export.

Notwithstanding their growing importance as fillers the kaolins from the Tuscaloosa are not being generally used in the ceramic arts in local enterprises, though a small quantity of firebrick is manufactured from them in Columbia, S. C. This may be due to a lack of some quality needful for ceramic purposes in competition with other clays or to a lack of consideration by ceramic manufacturers. The general distribution of the Tuscaloosa formation in South Carolina is shown in plate 1.

USE OF KAOLIN IN FIREBRICK

Columbia, S. C.—The R. M. Stork brick plant is 4 miles northeast of Columbia, S. C., on a branch road south of U. S. Highway 1. It is a small plant consisting of a mixer, a molder, and two kilns. The clay is obtained locally from small pits, is gritty and kaolinitic, and comes from the lower part of the Tuscaloosa formation. It is used practically as mined and made into standard-size bricks that burn white with some speckling of brown. These are marketed as firebricks.

Augusta, Ga.—The Babcock & Wilcox Co. has a large modern brick plant on the outskirts of Augusta to which additions are now being made. The plant specializes in high-test firebricks made into all sizes and shapes, of either the light aggregate or more massive type. The clays are derived from the mine of the Albion Kaolin Co., on Grindstone Branch, 1½ miles west of Hephzibah, Ga., and on the Georgia-Florida Railroad west of the area mapped in plate 2. The bricks are made by first burning the shrinkage out of the clay at a temperature well above 3,000° F. The resulting clinker or "grog" is then ground, molded into suitable form, and burned again into the final product. By mixing the grog with sawdust before molding and refiring, a very light brick is produced.

RUBBER CLAY

GENERAL PROPERTIES

The use of kaolin as a substitute for more expensive chemicals as a filler for rubber was not introduced until about 1920. Since then there has been a steady demand for and an increasing supply of kaolin for the rubber trade. The finest rubber clays, derived from the Atlantic Coastal Plain deposits, come from the vicinity of Aiken, S. C. They give to rubber greater tensile strength and resistance to wear.

These clays may be distinguished in the field from others not so suitable for rubber by certain physical qualities that become apparent only after extended experience. Rubber clays are particularly tough, though sectile when moist, and when dry they become crumbly with an irregular satiny to hackly surface. In wet weather a fresh mine face disintegrates readily. The color is usually a sallow buff and mottled where seen in the mine, and regardless of its superior quality as a rubber clay it never possesses the pleasing appearance of the fine paper clays. The better-quality clays bleach white and when pulverized yield a very white powder. Buff clays containing purple staining finish white.

These clays occur in the top of the Tuscaloosa formation and are exposed in Horse, Town, and Shaw Creek Valleys and beneath the highlands between these creeks. (See pl. 2.) This band of high-grade rubber clay is confined to western Aiken County. None of the clays observed to the northeast are of the rubber type, and likewise the Georgia clays, which excel in whiteness, lack the superior qualities possessed by the South Carolina clay for rubber.

LACK OF STANDARD PROCEDURE FOR COMPARING RUBBER CLAYS

It is unfortunate that no accepted standard test exists for rating the relative value of rubber clays, more especially for field comparisons. A letter received from the National Bureau of Standards in response to an inquiry concerning the evaluation of clays as rubber fillers contains an interesting statement of the present status of rubber tests:

This Bureau has set up no standard procedure for making comparative tests on fillers for use in rubber.

The methods now employed for such tests are, as you indicate, highly empirical. Each manufacturer, in testing a new filler, incorporates it in a rubber compound of the type or types in which he is interested. Many of the variations in test compounds are without basic significance. Some of the variations, however, are due to the fact that different manufacturers are concerned with different properties of fillers and accordingly use different formulas or conditions of test to best evaluate the characteristics sought. We think that it may be possible to employ not one but a limited number of test compounds for determining the relative merits of fillers.

So far as we are aware, however, there has been no serious effort made either to design any such standard test compounds or to promote their use by the trade. We are of the opinion that before any such effort can succeed, it will be necessary to have a broader and more fundamental knowledge of the mechanism of filler action, so that the results from a few general tests can be applied to any specific problem that may arise.

GEORGIA AND SOUTH CAROLINA RUBBER CLAYS COMPARED

A comparison of Georgia and South Carolina clays is given in the following table. Through the courtesy of W. J. Driver samples of kaolin selected in the field were submitted to the New York laboratory of the Huber Corporation for test. The Champion and Georgia kaolins were selected from mines in the Buffalo Creek area of Washington County, Ga. The Paragon and Suprex samples came respectively from the Alum pit and Graniteville mine of the Huber Corporation. These clays were prepared and mixed with the ingredients of the following "test recipe":

	Parts by weight
Smoked sheet rubber	50
Pale crepe rubber	50
Sulphur	3
Zinc oxide	5
Stearic acid	4
"Captax"	1
Clay (for test)	52
	165

Each mixture was then subjected to a curing process at a temperature of 260° F. for periods of 20, 25, 30, 45, 60, and 90 minutes, providing six time cures for each sample of clay. These samples were then subjected to mechanical test, the results of which are given in the following table, for comparison:

Comparative results of tests on South Carolina and Georgia crude clays

Cure at 260° F. (minutes)	400 percent modulus of elasticity	Tensile strength at break (pounds to the square inch)	Elongation (percent)	Hardness (shore)
Suprex				
20	680	1,800	640	48
25	850	2,400	640	49+
30	1,000	2,900	630	52+
45	1,200	3,400	630	56+
60	1,340	3,760	623	58+
90	1,485	3,960	618	61
Paragon				
20	500	1,640	655	46
25	700	2,200	640	49
30	825	2,740	640	51
45	1,080	3,280	630	55
60	1,190	3,360	625	58
90	1,225	3,280	612	60
Georgia kaolin				
20	400	1,640	690	46+
25	525	2,180	678	48
30	730	2,680	663	51
45	900	3,320	653	56
60	1,050	3,480	640	58
90	1,200	3,320	610	60
Champion				
20	500	1,740	670	46+
25	680	2,040	650	49
30	775	2,520	642	50+
45	890	3,000	630	55+
60	980	3,040	613	57+
90	1,160	3,040	580	60

The marked superiority of the Suprex clay is at once apparent by comparing the relative results shown in the table. Despite the greatly increased tensile strength and hardness imparted to the rubber, the comparative elasticity is not impaired. The mechanical tests for rubber show the Paragon clay to be similar in character to the best grade of Georgia clays, an agreement borne out by a comparison of their physical appearances.

A further comparison of different South Carolina clays of the Aiken area having value for use in rubber is provided by the following table compiled from information supplied by Fred Naegili, of the Southeastern Clay Co.:

Tests of rubber clays of Aiken County, S. C., 1934

Suprex

[Graniteville mine, Huber Corporation]

Cure at 288° F. (minutes)	300 percent modulus of elasticity	Tensile strength (pounds to the square inch)	Elongation (percent)	Set or hardness
10	567	3,873	667	38
20	713	4,243	647	47
30	790	4,207	623	54
40	940	3,793	590	55
50	1,000	3,285	530	51

Gunter No. 1

[Gunter pit, Southeastern Clay Co.]

10	607	3,920	663	41
20	750	4,140	633	51
30	827	3,983	607	58
40	893	3,700	580	63
50	1,027	3,510	555	57

Gunter No. 2

[Gunter pit, Southeastern Clay Co.]

10	603	3,960	680	41
20	757	4,375	655	53
30	850	4,107	613	59
40	913	3,805	575	59
50	1,013	3,560	570	59

Piper

[Piper pit, Southeastern Clay Co.]

10	550	3,803	677	39
20	710	4,100	647	50
30	750	4,190	630	56
40	860	3,490	573	51
50	953	3,580	565	56

Morris

[Morris pit, Southeastern Clay Co.]

10	617	3,597	640	41
20	757	4,047	633	51
30	870	3,970	600	53
40	910	3,715	575	56
50	963	3,420	543	56

Though the compounds used for the test mixtures were not recorded,[49] and the temperature and periods of cure were not equivalent to those employed in the previous determinations, the results are nevertheless sufficiently proportional to warrant comparative evaluation. Thus it is evident that there are many beds of clay in the Aiken area of superior quality for use in rubber.

[49] For data on rubber compounds see Weigel, W. M., Georgia clays: Rubber Age, July 25, 1924.

PAPER CLAYS

CHANGING CONDITIONS OF THE INDUSTRY

South Carolina undoubtedly once possessed the finest crude paper clays in the country and for many years was the main source of supply for the industry. The erosion of the Horse Creek Valley exposed large bodies of white clay of exceptional purity that required little effort to mine and no processing to supply the requirements of the market. Of late years the Georgia clays have captured much of this paper trade. This is due to a natural superior whiteness, to lower water absorption, and to the introduction of processing operations to remove grit and mica. Also recent prospecting in Georgia has uncovered extensive bodies of clay at shallow depth, whereas the cost of South Carolina mining has increased by reason of a steadily mounting overburden in the old mines. Many mines have been closed down for this cause. Also the natural advantage the South Carolina clay deposits enjoyed because of their exceptionally low grit and mica content has been materially offset by modern methods of cleaning the whiter though more gritty Georgia clays. The economic depression ushered in a new era in the clay industry when the seller's market was replaced by that of the buyer. Adjustment to new conditions set up by this competitive struggle has not been made by some operators.

The more precise specifications which the consumer now makes have resulted from competition by the crude clay producers to sustain markets. These specifications do not indicate passing conditions but an advance of the industry. The period of simple mining and marketing operations has ceased. Technical specifications in orders will become increasingly prevalent. Operations involving the processing of clays are tedious and expensive and require large capital investment, and deposits requiring such treatment are naturally avoided wherever possible. Though nature has been lavish with material and has provided clay beds of remarkable purity, the favorable conditions for simple enterprises that have prevailed in the past cannot long continue. The present trend is toward more elaborate plant operation and control, which will more completely utilize the clays mined and provide products of different grades. The crude clay will be trucked from mine to plant as nearer deposits give out. Thus processing plants will eventually be located at sites more suitable for economic operation than those now occupied.

USE OF GRADING TERMS

The classification of clays into grades (1, 2, and 3) in clay mines has significance only in the particular mine in which it is applied. It does not refer to any accepted standard. A No. 1 paper clay may be utterly different from a No. 1 rubber clay, but the terms indicate that from the producer's standpoint each of the two clays is the best grade of its kind in his mine. The quality of No. 1 clay differs from mine to mine. Those clays that are the whitest and most free from grit rate as No. 1 unless they are disqualified for some other reason.

COLORED CLAYS

Buff clay.—The buff clays are obviously stained by hydrous oxides of iron and usually contain both ferrous and ferric iron. As a rule the buff and colored clays are so gritty or micaceous that they are quite unsuited to commercial use. This grade of clay is occasionally used for cleaning peanuts. However, if the quality of the clay is otherwise excellent it may be used satisfactorily for fillers, pigments, or pottery in which color is of no consequence and in which a slight increase in iron content is not injurious to the finished product. The use of off-colored clays wherever possible will often save the manufacturer money and relieve the clay producer.

Black clay.—Many of the thicker clay beds have at or near the base a prominent black band that contains more or less organic material. In some deposits this layer is largely composed of vegetable matter and will burn. Much of it is made up of wood fiber. Such an organic clay streak extends from Aiken to Augusta. Usually the organic mat grades upward into a dark-colored or grayish clay of high plasticity and into either purplish-red or white clay. When dried the ebony-black clays turn to gray or grayish brown.

Purple clay.—The clays of South Carolina may be seen in almost all colors, but true yellows and greens are seldom encountered. Pinkish and magenta to red clays are common; these colors at many places grade into very strong purplish hues. The reds are obviously due to the presence of iron, and the purples may also be caused by some of the different oxides of iron admixed in different proportions. Field evidence suggests that carbonaceous material may have some part in this coloration, for many of the purple clays grade downward into black organic clays and upward into reddish clays, the purple color being induced possibly by some reaction between the carbonaceous material and the iron. Such a change was noted in a new cut of the Chicora pit, where the base of the clay bed was exposed A sample from this pit submitted to the laboratory of the Geological Survey for analysis was reported by J. J. Fahey to contain 0.18 percent of ferrous iron, 2.41 percent of ferric iron, and 0.05 percent of carbon. No test for manganese was made. A similarly colored sample of kaolin from the Lexington pit was tested for manganese, but no trace of it was found. Some of the clays, however, may contain manganese, because dendrites form along fractures in them.

Samples of pinkish to purplish clay were treated with pyroxol, and no change in color was observed. If any organic matter was present in the samples its removal by the pyroxol did not alter the original reddish or purplish color of the clay. Thus it seems doubtful if carbon is directly responsible for the purplish color of the clay. The coloring is undoubtedly due to some compound of iron, in the formation of which organic matter may have exercised a catalytic reaction.

TEST FOR PRESENCE OF IRON

A field test for the presence of iron in the white clays may easily be made by dipping small pieces in solutions of potassium ferro- or ferri-cyanide. Gradually the clay becomes colored a Prussian or a Turnbull's blue, and the intensity of the color or the rate of coloration gives some hint of the amount of iron present in the specimen.

OVERBURDEN RATIO

Field practice has shown that in general 4 feet of unconsolidated overburden can be economically removed from a clay deposit for each foot of marketable clay. The ratio of 4 to 1 has become the standard

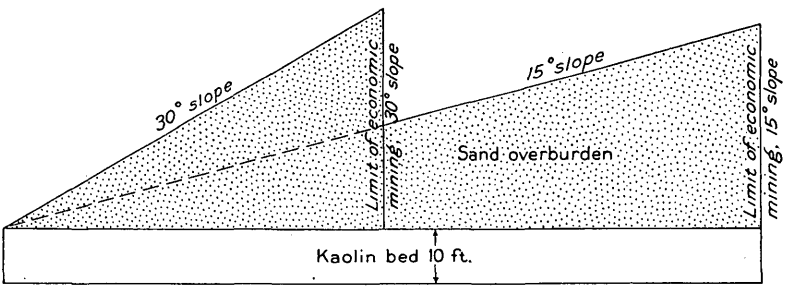
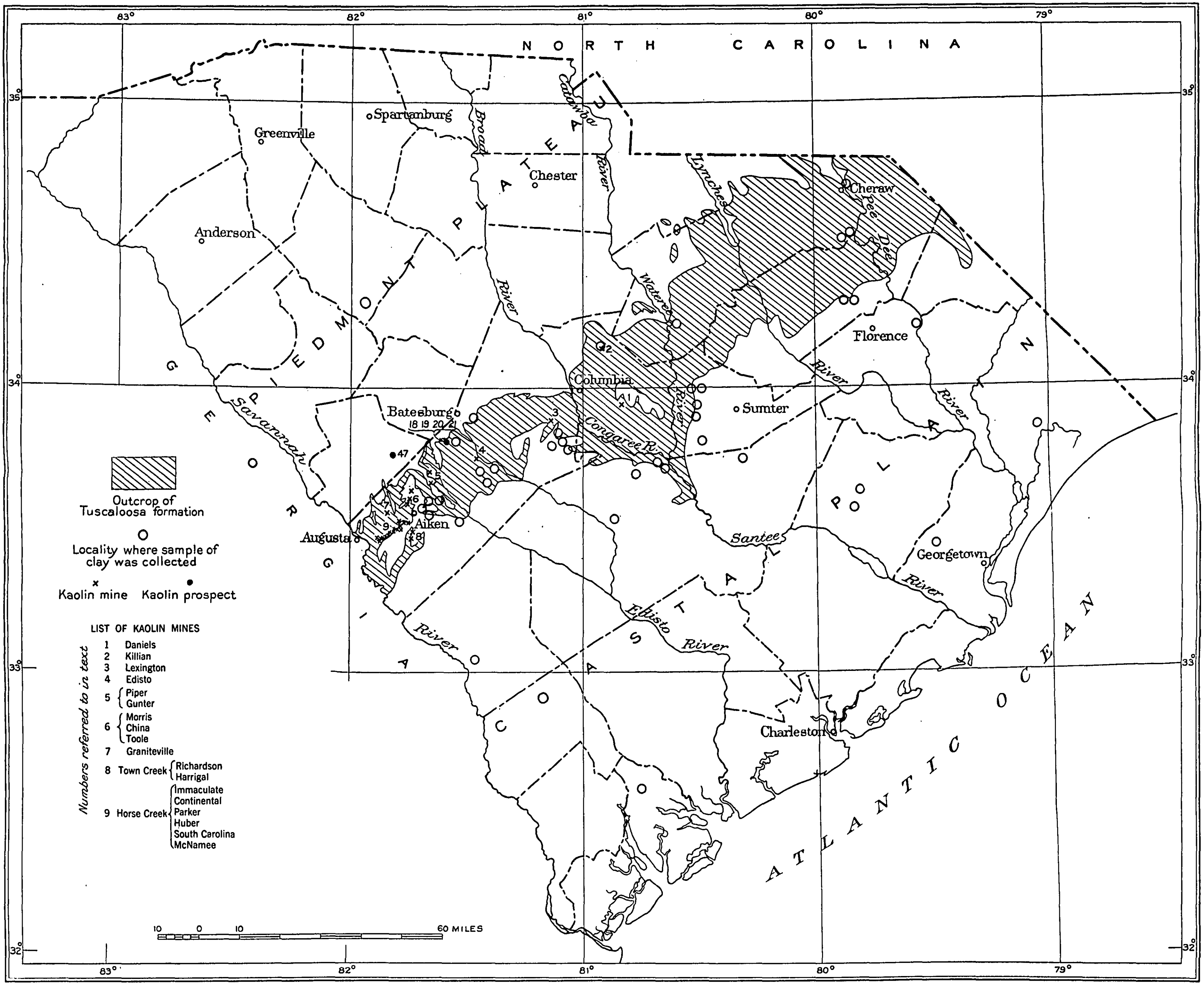


FIGURE 1.—Diagram showing effect of angle of slope on amount of kaolin economically available (4 to ratio) along a ravine.

limit. The thicker a clay bed the cheaper is the mining cost. Clay mines are of two kinds—(1) a pit sunk into a flat terrane with a relatively constant thickness of overburden, or (2) an outcrop along a ravine or slope where extended mining usually involves a mounting overburden. (See fig. 1.) Most mines are of the second type, and mining costs finally eat up profits as the more accessible clays are exhausted. The usual result is abandonment of the property for a more accessible deposit. Very little attention has been given to more systematic or improved methods of mining.

RESERVES OF KAOLIN

No estimate of the potential reserves of kaolin in the South Carolina field would be of particular value, because too little is known of the extent of the deposits already discovered, of the volume and quality of clay yet to be uncovered by more improved means of prospecting, and of the changes that new methods of mining and milling and the requirements of industry will bring about. At the



MAP OF SOUTH CAROLINA SHOWING OUTCROP OF TUSCALOOSA FORMATION, CLAY LOCALITIES, AND KAOLIN MINES.

present rate of consumption there are deposits in sight sufficient to last for many years, although it is also true that many of the high-grade clays within easy reach have been about mined out. As the clay industry is evidently entering a new period of activity based upon higher technical standards of mining, milling, and marketing, it will doubtless encourage further prospecting and improvements in mining methods and thereby bring about additional discoveries and an expanded reserve. Present supplies will be more thoroughly utilized, and clays now not considered of economic value will be added to production and reserves.

ROCK FORMATIONS OF THE AIKEN AREA

ROCKS OF THE PIEDMONT

The rocks of the Piedmont (see pl. 2) are of igneous and sedimentary origin, metamorphosed, folded, and faulted before the development of the old erosion surface upon which the Coastal Plain deposits were laid. Unweathered rocks of the Piedmont are easily distinguishable from the Coastal Plain deposits, but where they are deeply weathered and exposures are poor they can be identified in the field only with difficulty. In places certain phases of the red-weathered rocks of the Piedmont and the red Barnwell sand are indistinguishable. The appearance of angular quartz float denotes the presence of a Piedmont surface. The irregular topography of the Piedmont area is often in contrast with the more even surface of the Coastal Plain. This is very likely due to the fact that the rocks of the Piedmont are subject to further chemical alteration and disintegration, whereas the Coastal Plain is composed of the thoroughly reduced end products of weathering derived from the ancient Piedmont and deposited in their present location. The rocks of the Piedmont were undoubtedly deeply eroded in pre-Cretaceous time, but as the Cretaceous sea advanced upon the land much of this disintegrated material was removed to form the insoluble deposits of the Cretaceous. In some places the weathered material was completely removed, exposing fresh rock surfaces, but in protected areas some weathered rock remained to form the floor for the new deposits. Chemical weathering of the buried floor undoubtedly continued, but at a much reduced rate. Now when this blanket of inert Coastal Plain deposits is removed by mechanical weathering, a less resistant surface is exposed. Consequently the Coastal Plain deposits usually end in a northwestward-facing scarp, beyond which lies the Piedmont with an irregularly dissected surface. As the Coastal Plain deposits are eroded away a new pattern of secondary drainage develops on the rocks of the Piedmont thus exposed. The master streams are the chief survivors. The young streams of the Piedmont have steeper gradients as a rule and weaker rocks to work upon. Though the rocks of the Piedmont in depth are hard, dense, and resistant, weathering is so deep that in many places streams have not cut down to the hard underlying rock. The master streams are continuously turbid from a constant supply of silt from the Piedmont.

DEPOSITS OF THE COASTAL PLAIN

TUSCALOOSA FORMATION

GENERAL CHARACTER

The Tuscaloosa formation (see pl. 1) is essentially a coarse-grained unconsolidated sandstone with intercalated beds and lenses of kaolinitic clay. The formation is white to buff with occasional variegated tints furnished by the clayey zones. The sands are commonly cross-bedded and channeled, and locally bedding planes or top-set beds are plainly visible. Details of the formation as exposed in a boring on the property of the J. M. Huber Corporation, Langley, S. C., are given on pages 34–41. Quartz probably constitutes 90 percent of the formation. The individual grains are sharp and average about 1 millimeter in diameter, but with increasing size of grain there is more evidence of rounding. Mica and kaolin are the common associates of the quartz sands. The kaolin occurs either as a clayey component of the sands or more definitely concentrated in lenses or extensive beds 40 feet or more thick. The kaolin varies in purity, color, and quality. These changes may take place gradually or abruptly, both laterally and horizontally. Locally kaolin beds are of amazing purity and whiteness. The economic clays are near the top of the formation. The clays of the lower part of the Tuscaloosa are more apt to be micaceous, gritty, and discolored. This may well be seen in the railroad cuts of the Georgia & Florida Railroad north of the Martintown road. (See fig. 2.) The contact of the Tuscaloosa formation with the rocks of the Piedmont is seldom visible, and except at one locality noted the grain size of the beds immediately in contact with these rocks is only slightly coarser or more angular than in the main body of the formation. The rocks of the Piedmont at the contact are invariably weathered and commonly colored white to buff.

The Tuscaloosa formation has a very slight dip to the southeast and lies essentially as it was deposited. In Tuscaloosa time the material of the formation was retransported and redeposited many times before finally coming to rest.

HUBER TEST WELL

Conditions at drilling site.—Through the courtesy of Mr. Wilber Driver, of the Huber Corporation, labor and equipment were supplied for drilling a test well through the Tuscaloosa formation. A site was chosen approximately 100 feet southeast of the Huber-Langley clay plant, which is 1½ miles south of Langley, S. C., on the south side of Horse Creek. (See pl. 2.) At this drill site the kaolin bed has been mined out. Some 300 feet to the south this clay bed may be seen in a new pit, where it has an almost imperceptible dip to the southeast and is overlain by more than 55 feet of Tuscaloosa sands. Above the Tuscaloosa lies 50 feet of Barnwell sands, the top of which is a regional plain of erosion, which in this area has an altitude of 450 feet. The altitude of the drill site is approximately 345 feet.

Drilling method.—The drilling equipment consisted of a light portable wash rig driven by a gasoline engine and capable of handling 20-foot lengths of 1- and 1½-inch iron-pipe rods. Fishtail bits 3 inches or less in diameter were supplied with water for drilling by a single-stage reciprocal pump. The bit was given a chopping action by snubbing the elevator cable on the elevator drum. This type of drilling equipment is capable of penetrating only disintegrated or unconsolidated formations.

Drilling by this method involves two operations, the chopping action of the bit and a jet action of the injected drilling water, which in these unconsolidated sands is at times sufficient to perform the function of drilling. Manual rotation of the drill pipe rounds out the hole. Cuttings are carried to the surface by the return circulation, and samples are caught upon a fine wire-mesh screen. Casing is set by driving with a 400-pound hammer and recovered by the use of manual jacks. Caving sands are often indicative of water-bearing beds and when water sands are encountered it is usually advisable to set casing. When caving sands shut off the return-water circulation, the recovery of drill rods and bit becomes a difficult task with a light rig.

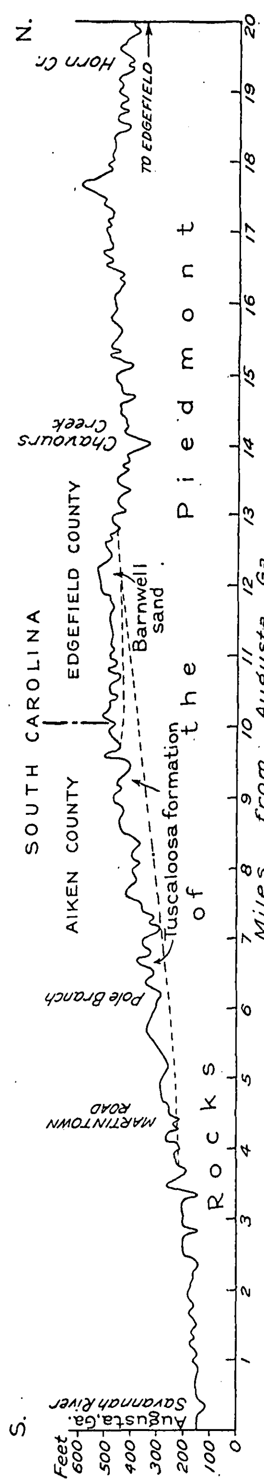


FIGURE 2.—Profile showing outcrops of the Tuscaloosa formation and the Barnwell sand along the Georgia & Florida Railroad. Railroad profile furnished by the engineering department of the Georgia & Florida Railroad.

The test.—The first test hole was drilled to a depth of 230 feet and was lost when a cave-in locked the rods. The rig was then moved to a new location 15 feet west and a new hole drilled to a depth of 290 feet. A quartz cobble, encountered and sidetracked at 275 feet, slipped back into the hole and locked the rods at 290 feet. As the capacity of the rig had been exceeded, it was considered advisable to abandon further drilling, and the test was converted to a water well. The unfortunate encounter with the quartz cobble was regrettable, because the base of the Tuscaloosa was expected at a depth of approximately 300 feet. The dip of the Piedmont surface beneath the Tuscaloosa in the Warrenville quadrangle is 25 feet to the mile southeastward. Locally the rate appears greater, and this must be true at Horse Creek in the vicinity of Langley, for a projection of the stated dip from the outcrop in Little Horse Creek intercepts the test well at a depth of 290 feet.

Section exposed.—The following generalized section compiled from the detailed results of microscopic study of the samples obtained (see pp. 35–40) shows the broader lithologic features of the Tuscaloosa formation at the drilling site.

Section of Tuscaloosa formation at Huber test boring

	Thickness (feet)	Depth (feet)
Clay, white, exposed in outcrop and in old Paragon clay pit	----------	----------
Clay, top of boring, white kaolin with admixture of white mica and clean quartz grains (sample 1)	15	15
Sand, sharp sand grains comprising 75 to 90 percent of whole; admixed kaolinite and mica, dark minerals less than 1 percent (samples 2–5)	30	45
Mica-bearing streak; mica makes up 75 to 80 percent of sample with admixed white clay and quartz grains (sample 6)	1	46
Sand; quartz grains comprise 65 to 90 percent of material and range in size from 0.25 to 1 millimeter. Mostly light-colored; kaolinite and mica, together with a few grains of dark minerals, make up the rest. A 1-foot seam of kaolin at 100 feet (samples 7–16)	54	100
Gravel, grains chiefly quartz, 2 to 5 millimeters, some red grains of altered porphyry (?), no mica or clay (sample 17)	5	105
Sand, chiefly quartz grains ranging from 0.5 to 2 millimeters in size, muscovite mica, kaolinite scanty, few dark mineral grains (samples 18–29)	70	175
Conglomerate, practically all quartz grains, some as much as 4 millimeters in diameter. Finer material locally as much as 50 percent of whole. White mica grains 0.25 millimeter inconspicuous. No kaolinite observed (sample 30)	5	180
Sand, grains 2 millimeters or less, fairly clean quartz, little kaolinite, some dark mineral grains, mica more or less conspicuous. Light color, locally pinkish (samples 31–37)	35	215
Sand, quartz grains averaging about 1 millimeter, very conspicuous showing of heavy minerals, all fine-grained, little kaolinite (sample 38)	5	220
Sand, quartz grains 0.5 to 1 millimeter, few dark mineral grains, micaceous, slightly grayish color. Bottom of first well (samples 39–40)	10	230
Continuation in second well:		
Sand, quartz grains very whitish, clean, few mica flakes, no clay minerals, only few specks of dark minerals (sample 41)	5	235
Conglomerate, quartz grains 3 to 4 millimeters, slightly smoky. No mica, dark minerals, or clay minerals (sample 42)	5	240
Sand, quartz grains ranging from 0.5 to 3 millimeters, mostly in smaller sizes, light color, mica more or less abundant, little clay (samples 43–47)	25	265
Conglomerate, largely quartz grains as much as 4 millimeters, mica and dark minerals not conspicuous, no kaolinite (sample 48)	5	270
Sand, quartz grains ranging from 0.5 to 3 millimeters; smaller sizes dominant, mica and dark minerals generally inconspicuous; no kaolinite (samples 49 and a–c)	20	290

Samples obtained.—The samples collected from the test well are described below:

	Depth (feet)
1. White kaolin with admixture of white mica flakes and sharp clear quartz grains. Base of clay bed in the old Paragon clay pit. (NOTE.—Samples from the first 60 feet represent a continuous record though they were caught from the footage intervals recorded. The material within any gap is essentially that of the succeeding sample.)	8–10
2. Sharp sand grains, average ⅓ millimeter, 75 percent of sample. Thin transparent plates of white mica of less than 1 millimeter. Foliated translucent kaolinite crystals. Less than 1 percent of dark materials	15–18
3. Sharp quartz grains, same size as above, transparent mica plates slightly larger size to 1 millimeter	23–29
4. Sharp quartz grains, ⅓ millimeter. More than 90 percent of sample quartz. Clear. Transparent mica. Kaolinite crystals in blocks, 0.25 millimeter, no evidence of rounding of grains. Few black minerals. Occasional large plates of transparent mica 2 millimeters across. Few iron-stained quartz grains, brownish to reddish	32–34
5. Practically the same as above sample in type and percentage of quartz. Kaolinite crystals 0.5 millimeter 5 percent of sample. Brilliant white mica less abundant than kaolinite. A few black and some brown grains present	39–40
6. Mica, 75 to 80 percent of sample, with white clay. Size of associated quartz 0.5 millimeter. Many of quartz grains contain iron inclusions. Brown iron-stained kaolinite crystals. Heavy minerals, muscovite abundant, no biotite recognized, staurolite, tourmaline, euhedral zircon, sillimanite, monazite, ilmenite, magnetite	45–46
7. Quartz, 65 percent of sample. Sufficient brown grains of residual iron to give color to the sample. Slight buff color, especially when wet. More clear mica than kaolinite grains present. Finer angular quartz grains 0.25 millimeter in diameter also present	51–52
8. Quartz, 95 percent of sample increasing in size to 1 to 1½ millimeter. Transparent mica plates more conspicuous in a wet than a dry sample. Large kaolinite crystals as much as 2 millimeters. Some quartz iron-stained. One tourmaline crystal shows good rounding. The largest quartz grains also give evidence of rounding. Heavy minerals, staurolite, red rutile, cyanite, tourmaline, zircon, sillimanite, muscovite, ilmenite, magnetite	57–60

	Depth (feet)
9. Quartz grains, sharp, 0.5 millimeter in diameter, with abundance of white mica, corroded edges. A little black mineral and grains of iron oxide; 5 percent of white kaolinite crystals; muscovite mica probably equals 15 percent of sample	60–65
10. Same as sample 9	65–70
11. Practically same as sample 9 except slight increase in mica content and less iron-stained grains. Very few dark heavy minerals. Sample presents a remarkably whitish appearance	70–75
12. Quartz grains, coarse, sharp, 1 millimeter in diameter, 85 to 90 percent of sample. Abundance of large kaolinite crystals	75–80
13. Coarse sharp quartz, 1 millimeter, showing a dominant elongate appearance as if derived from a gneiss, makes 90 percent or more of sample. Few dark grains. Very few kaolinite crystals. Iron-stained grains present. White mica 5 percent or more	80–85
14. Relatively same as sample 13	85–90
15. Practically same as sample 13 but slightly more kaolinite	90–95
16. Quartz grains slightly smaller. Percentage of white mica greatly increased, possibly 15 to 20 percent of sample. Very little color from iron oxide grains or black minerals. Kaolin seam 1 foot thick at 100 feet	95–100
17. Abrupt change to gravel. Grains average 2 to 5 millimeters across. Most of grains slightly frosty, few smoky, few large red grains appear like fragments of altered rhyolite porphyry, red ground-mass, well rounded, 6 millimeters. Some iron-stained quartz. All grains show some wear. The larger the grain the more rounding. No mica. If clay were present it has been washed out during drilling	100–105
18. Range of quartz grains 0.5 to 2 millimeters. Quartz fragments sharp, larger grains probably hang over from bed above. Little white mica. Practically no evidence of clay. Sample remarkable for whiteness. No color from iron oxide or black minerals. Some quartz frosty. Quartz veined with lacy fractures	105–110
19. Remarkably clean sand. Quartz grains frosty, slightly rounded. Frostiness is both inherent in quartz and amplified by abraded surface. Few kaolinite crystals. Absence of mica and colored minerals. Grain size 1 to 2 millimeters	115–120
20. Same as sample 19 but slightly coarser. Few muscovite flakes. Some quartz shows minute dark inclusions. Quartz clearer and sharper than above, even some large quartz crystals show knife-like edges	120–125
21. Mixed grains of quartz sand 0.5 to 2 millimeters. Same type of grains as above, frosty, few limonite grains, none black. Mica more evident	125–130

	Depth (feet)
22. Practically same as sample 21. Grains slightly coarser. Some flecks of pyrite in quartz	130–135
23. Somewhat same as sample 22. Considerable smoky quartz grains, which give a greyish tint to the sample. Grains equidimensional, dominant size, 2 millimeters. Few mica flakes present in sample, though much may have been lost during washing on screen. Practically no clay minerals, black or iron-stained grains	135–140
24. Sample more whitish than above, fewer smoky grains. Grain size slightly less than above, 1½ millimeters. Tendency to elongate shape. No dark minerals, clay or iron-stained grains present. Mica not evident	140–145
25. Slightly coarser sand, frosty to smoky. About 2 percent of white mica flakes. No clay minerals. Some colored heavy minerals. Dark brown to black quartz grains, equidimensional, coarse and not much rounded	145–150
26. Quartz, 1 millimeter. Little mica. Quartz sharp, clear, few colored grains	150–155
27. Quartz grains, 1 to 2 millimeters, dominant. Mica shows plainly. Sample has a dull smoky cast. No clay minerals, few iron-stained specks. Very few black heavy minerals	155–160
28. Dry sample contains considerable fine clay dust, denoting presence of a thin clay bed with the sand. Quartz, 80 to 85 percent. Some mica. Some white kaolinite crystals. Quartz clear, sharp, 0.5 millimeter average size. Some limonite and black grains, though not prominent. Kaolinite crystals have wavy plates very much like compressed fish scales	160–165
29. Very clear white sand, 0.5 to 1 millimeter. Sharp. Mica scarce. Kaolinite crystals	170–175
30. Conglomerate 2 to 4 millimeters. Practically all quartz. Glassy, frosty, and smoky, giving a milky to smoky appearance. Few pale-yellow and pink grains. There is at least 35 percent of fine sharp sand present, which is not conspicuous when the sample is wet. The white mica is of uniform size (0.25 millimeter) and most inconspicuous. No kaolinite crystals observed	175–180
31. Smaller-grained sand than above (2 millimeters). Very clean, practically no color. Most grains equidimensional and sharp. Some milky. Smoky variety absent. No kaolinite crystals. White mica scarce. Small flakes of 0.5 millimeter or less	180–185
32. Fine clean sand. Clear to frosty with a few grains of rose-pink to faint-yellow color. Smoky tint not apparent. Mica scarce. No kaolinite crystals. Grain size of quartz 0.5 to 2 millimeters. Quartz grains blocky and show some smoothing of the edges	185–190

	Depth (feet)
33. Sample much the same as sample 32	190–195
34. About the same as sample 32 except small flakes of mica becoming more prominent and small brown (limonite) grains. Very few kaolinite crystals	195–200
35. Sand grains slightly coarser and more variable in size. Mica conspicuous, probably 5 percent of sample. Quartz grains slightly grayish, show slight rounding of sharp edges. One 2-millimeter grain very well rounded. Some dark minerals	200–205
36. Sand grains 1 to 2 millimeters, uniform pale-gray tint. Practically no black mineral. Mica conspicuous but not over a few percent. No obvious clay minerals	205–210
37. Grains slightly coarser. Some mica visible. Most quartz grains are clear; a few milky, and some are a faint pink or yellow tint. Though quartz fragments are angular, there is evident polishing off of the edges and corners	210–215
38. Quartz sand, medium grain, averaging about 1 millimeter. Quartz about same as in sample 37. Few spangles of mica. Very conspicuous showing of heavy minerals, all fine-grained. Fair sorting for size of quartz and rounding of the grains, black, brown, rose, amber, yellow, green. Heavy mineral chips show some rounding of edges but are still sharp. Few kaolinite crystals. Heavy minerals, staurolite, tourmaline, muscovite, blue tourmaline, ilmenite, magnetite, biotite?	215–220
39. Grains of quartz slightly larger than in sample 38 and uniform. Mica more apparent. Heavy minerals absent. Not much evidence of rounding	220–225
40. Very clear even-grained sand averaging about 0.5 to 1 millimeter. Uniform color, slightly grayish. A very little white mica and a few specks of dark minerals, of the same nature as in sample 38. Quartz grains uniform, sharp, and equidimensional. Bottom of first well	225–230
41. Sample continued in second well. A very whitish, clean even-grained quartz sand. Very little color present and only a few full specks of heavy minerals. Mica represented by but a few flakes. Clay minerals absent	230–235
42. Conglomerate, grains 3 to 4 millimeters, slightly elongate. Color slightly smoky. Very little other color present. Mica absent, also dark minerals. Very slight rounding of the outer edges of the quartz grains. Reentrant faces appear not to have been abraded. On some grains the polishing marks on the rounded points are plainly evident. No clay minerals	235–240

	Depth (feet)
43. Quartz sand, 1 millimeter average diameter, relatively uniform. Grains fairly equidimensional, color pale gray. A few iron-stained grains, very small. Few fine heavy minerals present similar to those in sample 38. No clay minerals. Mica evident. Quartz grains sharp, very little evidence of smoothing of points of grains. Some very sharp angles are left unaffected; others seem to indicate a faint dulling of the edges	240–245
44. Quartz of a pale-grayish tint, though neither the smoky nor the frosty variety of quartz is conspicuous. Average grain size about 1½ millimeters; small percentage exceed 2 or 3 millimeters; these are of the milky variety. Mica evident, in small flakes. Heavy minerals conspicuous but very small and very few in number. No clay minerals	245–250
45. Same as sample 44 except that practically no mica is present	250–255
46. Quartz grains averaging 0.5 to 1 millimeter, 99 percent. A few smoky quartz crystals of 2 millimeters or more. Sample whitish. White mica very scarce. Heavy minerals very scarce and fine. Quartz grains sharp	255–260
47. Quartz sand, grain size variable, ranging from 0.5 to 2 millimeters. Large grains of milky quartz. Sample presents a whitish to grayish tint. Mica present but not very evident. Occasional kaolinite crystals seen. Heavy minerals very scarce and small. Quartz sharp; little evidence of surface corrosion	260–265
48. Conglomerate. Considerable variation in grain size, ranging from 4 millimeters to a mass average of 0.5 millimeter. Surprisingly little evidence of rounding on even the large grains of quartz. Color pale grayish to milky. Mica and dark heavy minerals not conspicuous. No kaolinite crystals. Large quartz grains very irregular in shape but equidimensional. Much of the transparent quartz appears as shatter quartz—that is, the original crystal has been broken by stress into fragments which fall apart when transported	265–270
49. Quartz sand, grain size variable, 0.5 to 3 millimeters; a few small mica flakes. No kaolinite crystals. Few heavy minerals. Many of the quartz grains are pale pinkish to rose-colored. As usual, most of the quartz is fragmentary, with only the faintest show of smoothing of sharp edges	270–275
—. Quartz sand, average grain size less than 1 millimeter, rather uniform, equidimensional, and sharp. No kaolinite crystals. Some pink and yellow quartz. Dark heavy minerals very scarce and of small size Mica very scarce	275–280

	Depth (feet)
Samples representing interval of 280–290 feet taken every 3 feet. Samples marked a, b, c, as their proper order was lost by driller failing to mark samples	280–290

a. Sample similar to that at 275–280 feet, with a scattering of coarser smoky grains of quartz. Lightest in color of series. Contains white mica flakes conspicuously scattered through the sand. Grains uniform and fine, less than 1 millimeter. Meager representation of heavy minerals.

b. Slightly coarser than sample a and a shade darker. Mica flakes larger and a bit more numerous than in sample a, though less than 1 percent of sample. Quartz 98 percent of sample.

c. Coarser and grayer than sample b. Gray quartz, over 1 millimeter in diameter. Possibly 10 percent of 2 millimeter quartz grains. Mica present but practically no heavy minerals. No kaolinite crystals.

Samples a, b, and c were combined for a heavy-mineral determination. A very meager crop resulted, consisting of staurolite, tourmaline, zircon, ilmenite, and magnetite.

Source and character of kaolinite crystals.—Examination of the samples revealed the very interesting fact that no feldspars occur in any part of the section. This agrees with what has been observed of the surface exposures of the Tuscaloosa in Aiken County. Although it cannot be denied that arkosic sands may be present in the formation, observations of the character of these beds render this unlikely. Kaolinite crystals occur in abundance in the upper part of the well, but are probably secondary, as it is hardly conceivable that they could have retained their form during transportation along with the sharp sand grains. The crystals probably grew in the interstitial spaces between the quartz grains from kaolinitic material originally developed in the altered rocks of the Piedmont and transported with the sands to the site of deposition, or their constituents were later introduced by ground-water circulation. In some samples these kaolinitic crystals are as abundant as the mica flakes. They are usually blocky, six-sided translucent crystals. When wet they appear very much like foliated mica, but when dry they are chalky and so suggestive of decomposed feldspar that they might well be mistaken for it. Such occurrences may have suggested the classification of some Tuscaloosa sands as arkoses. When thoroughly wetted and pressed with very slight pressure by tweezers the kaolinite crystals break down into a pile of thin nonelastic grayish flakes. This is not true of the muscovite, which is fresh, elastic, transparent, and resistant to crushing by the tweezers. Most of the muscovite plates show corroded edges.

Size and character of other mineral grains.—Selective determinations of grain size of other minerals have not been made, but from random measurements it is estimated that the average grain size is about 1 millimeter. The grains are sharp, clear, and composed of quartz. Aside from the smoky and milky quartz present only a very few grains in each sample show color. As the grain size increases to 3 or 4 millimeters rounding becomes more evident, and the conglomeratic sands show considerable abrasion. In no samples were heavy minerals present in noteworthy quantity. The apparent absence of biotite in samples in which other mica minerals are abundant is suggestive of the character of the source rock. However, this cannot be accepted as conclusive evidence, for biotite readily bleaches to a colorless mica.

Kaolin a minor constituent of the Tuscaloosa.—Although the bedded exposures of kaolin as seen in the field are most conspicuous, kaolin deposits are nevertheless a minor constituent of the Tuscaloosa formation. It is worthy of note that only one notable clay bed and two minor seams were present in the 290-foot well section and the accompanying 55-foot thickness of outcrop. A 2- to 3-foot discolored clay seam lies at the top. The next clay bed below is the 15-foot commercially valuable kaolin layer which occupied the first 10 feet of the well section and is now replaced with roughage. A 1-foot seam of clay lies 100 feet below the surface at the well site, the last of any significance encountered in the section.

LENTICULAR DEVELOPMENT OF CLAY

According to current information, prospecting in the general area during the early period of the clay industry had revealed the presence at depth of "a thick bed of clay superior in quality and whiteness to that found at the surface." Although the Huber test disclosed only a 1-foot representative of this clay lens, a water well also drilled during the spring of 1935 encountered, according to the driller, a thick bed of good white clay. Its site was 1 mile a little to the south of east of the Huber test, 50 feet east of the Pine Log road, midway between the Immaculate Kaolin Co.'s plant and the Harmon store. The driller's log, transcribed from memory, is given below.

Driller's log of water well 1 mile southeast of Huber test well, Aiken, S. C.

	Depth (feet)	Thickness (feet)
Gravel	10	10
Buff gravel	40	30
Pink clay (?) [more likely a clayey sand]	59	19
Good white clay	100	41
White sand	165	65
White clay	190	25
Coarse gravel; water at 227 feet	227	37

Stratigraphically the 25-foot bed of clay at 165 to 190 feet corresponds to the bed at 100 feet in the Huber test well, where it has lensed out to a little more than 1 foot in thickness. As to the quality of the clay, nothing can be said, as samples were not seen. Obviously, the amount of overburden makes this clay bed of no commercial value, for the present at least.

The 37 feet of coarse gravel reported by the driller was probably composed largely of 2- to 3-millimeter grains of quartz. Well-rounded quartz pebbles as large as 1 inch in diameter occurred at the bottom of the well.

Both clay beds lie within the upper part of the Tuscaloosa.

FOSSILS

During the field investigation no marine fossils were discovered. Stephenson [50] has reported finding one oyster shell in the Tuscaloosa. Fragments of leaves and wood are relatively common. The basal part of the black clays is often composed of fragments of wood an inch or more in diameter and in a fair state of preservation. Leaves are the most common organic remains and are found here and there in thin clay seams intercalated with the sands. Many well-preserved leaf impressions were found in the bottom 1 foot of clay in the Morris pit. Although there is a plentiful supply of material, the number of species represented is small.

THICKNESS

The results obtained from the Huber test well and an examination of the samples lead to a better understanding of the character of the Tuscaloosa formation in Aiken County. Unfortunately the bottom of the formation was not reached by the drill, nor is it known how much of the formation was removed by erosion during later Cretaceous and early Eocene time prior to the deposition of the Barnwell. The formation is cut off by erosion within 12 to 15 miles northwestward from this locality. By adding the section uncovered by the drill test to that shown on the outcrop, a minimum thickness of 350 feet of Tuscaloosa at the drilling site is recorded. Unless there is some unusual change in the configuration of the Piedmont surface, an additional 25 feet is all that may be safely added to the base of the formation. For the upper portion there is a less certain limit, but it may be assumed with safety that the Tuscaloosa in the Horse Creek area was at least 400 feet thick.

The average width of Tuscaloosa exposures measured from the contact with the rocks of the Piedmont to the overlapping margin of the Barnwell or McBean formation is 15 miles. At a dip of 25 feet to the mile, a thickness of 375 feet is obtained. This inclination of 25 feet to the mile for the old pre-Cretaceous erosion surface was determined

[50] Stephenson, L. W., personal communication.

locally from exposures in the Warrenville quadrangle and checks favorably with a regional measurement covering the distance from Aiken to Summerville, S. C., where a well is reported to have encountered basement rocks at 2,450 feet. A corrected estimate gives a dip of 23 feet to the mile, but as the direction of measurement is probably oblique to the strike of the old erosion surface on the basement rocks, the figure 23 feet is too low.

McBEAN FORMATION

The McBean formation is composed of sands and marl. The greenish tinge of the sands is of great aid in recognizing their presence in an outcrop. The sands also contain black carbonaceous streaks and small irregular marly inclusions. The marl beds in the lower part of the formation contain fossil sea shells. A very fossiliferous outcrop occurs at the water's edge on the southeast bank of Tinker Creek near Reedy Branch. Exposures of the McBean are also to be seen along the highway near Ellenton, in southern Aiken County. The McBean overlies the Tuscaloosa in southeastern Aiken County but was removed by pre-Barnwell erosion in the northwestern half. In Town Creek and along the upper slopes of the south bank of Horse Creek the basal sands above the Tuscaloosa have a faint greenish cast. It is believed that these sands are of Barnwell age and derived from the McBean, but they may be thin isolated remnants of McBean. The McBean tapers off in the area between upper Three Runs and a line following Halley Creek to Montmorenci, and across the Savannah in Georgia it does the same.

BARNWELL SAND

The Barnwell formation lies unconformably upon both the Tuscaloosa and the McBean. It is composed essentially of unconsolidated buff to deep-red clayey sands and has a buhrstone member that is locally prominent. Laminated clay beds are also present within the sands. The most striking feature of the Barnwell is the very deep red color that it assumes in places. The reddest deposits, however, contain less than 6 percent of iron, most of which is in the ferric state. Partial weathering appears to intensify the reddest coloration, and as usual rain wash gives a false coloration to surfaces below it. Thus more rocks as exposed at the surface appear deeply colored than are actually so. The Barnwell overlaps the Tuscaloosa (see fig. 2) to the northwest, where it lies directly upon the Piedmont rocks. Where the weathered rocks of the Piedmont and the Barnwell are both composed of red quartzose clay they are very difficult to distinguish, except where road cuts provide fresh sections. The Barnwell usually contains a scattering of rounded pebbles, which are of great assistance in distinguishing it from either the rocks of the Piedmont or the Tuscaloosa. Rounded pebbles are obviously not a part of the Piedmont rocks, and water-worn pebbles seldom occur in the Tuscaloosa. The thickness of the Barnwell is usually 50 to 100 feet. North of Horse Creek it tapers off, but southeastward the formation thickens and may in places approach 200 feet where it lies on irregular surfaces of older deposits.

To distinguish the Barnwell from the Tuscaloosa is one of the most important problems confronting the clay prospector. Even where open cuts have exposed good sections it is not always easy to locate the contact. Cooke considers the presence of well-rounded and polished pebbles a fairly safe indicator of the Barnwell. A certain

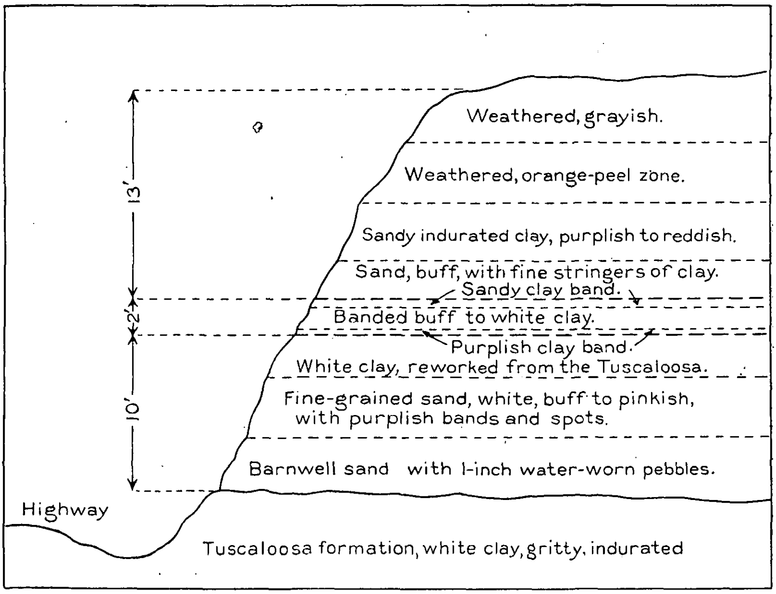


FIGURE 3.—Section of Barnwell sand showing details of formation and contact with underlying Tuscaloosa, Augusta-Trenton highway, 4 miles south of Trenton.

sequence of beds is, however, fairly common in the basal portion of the Barnwell and where present is of great help in fixing the stratigraphic position of the section. Water-worn pebbles ¾ to 1½ inches in diameter usually lie within a foot or two of the base and at the contact. From 10 to 20 feet higher the buff to variegated sandy Barnwell grades into a well-laminated clay band that is variable in thickness, color, and extent. The clay band is usually buff to brown but may be pinkish to purplish. The most significant characteristic is a distinct alternation of bands of clay and sandy clay an inch or two thick. (See fig. 3.) This zone may exceed 10 feet in thickness or may feather out completely. This facies of the Barnwell, which is considered marine, is followed by clayey sands locally cross-bedded like those below and usually weathered brilliant red. If this typical

Barnwell sequence overlies an irregular surface of white kaolin the stratigraphic position of the exposure may be considered definitely determined. In some exposures both the pebbles and the laminated bands are absent and the Barnwell lies upon Tuscaloosa sands. Here correlation may be made by running levels to more definite exposures, or more detailed comparison of deposits at different exposures may be necessary to determine the stratigraphic position of a particular bed.

Buhrstone.—Deposits of buhrstone occur at or near the base of the Barnwell. They are composed of variable amounts of coarse sharp quartz grains and fossil shells. The original calcium carbonate of the shells has been completely replaced by silica, and usually many of the interstices between the shells and quartz grains are filled with opaline silica. Grinding wheels for milling corn were cut from buhrstone and are in use throughout the South in rural districts. Buhrstone forms a ledge in the upper end of a tributary of Bridge Creek in the Warrenville quadrangle. This ledge, which is 4 to 6 feet thick and but 100 feet or so wide, occurs on both sides of the valley. It has a northeast strike and reappears north of the Morris pit in upper Bridge Creek. Still farther northeast the iron-stained conglomeratic phase of the Barnwell is exposed along the Edgefield road and across Shaw Creek above Shiloh Church. Another very massive outcrop of burhstone 15 feet thick is present about Dibble's Pond and is reported to underlie most of the Montmorenci Plains at a depth of approximately 100 feet. It is claimed that the buhrstones underlie the surface depressions and that drilling through the buhrstone beds permits a lowering of the water table.

Pebbles.—The typical Barnwell pebbles are of very smooth, well-polished quartz. They are usually about 1 inch in diameter, flattish, and composed of clear milky to dark smoky varieties of quartz. Many of the pebbles are coated with an iron stain. These may be confused with the concretionary iron pebbles found in many places scattered through the Barnwell and are locally abundant near its base. They are gritty clay pellets derived from fragments of older deposits and coated with a hydrous iron oxide shell one-eighth to one-fourth inch thick. These concretionary pebbles occur in quantity at the contact of the rocks of the Piedmont with the Tuscaloosa and Barnwell formations on the Edgefield highway just east of the Trenton quarries.

Gravel of another type, which reaches the size of cobbles, may or may not be of Barnwell origin. Some of this gravel forms terraces along Horse Creek and was deposited during the cutting of Horse Creek Valley. The cobbles are about 3 to 4 inches in diameter and consist of quartz, usually water-worn and in different stages of decay. Some are of fresh massive smoky vitreous quartz ,but others crumble into grains when crushed in the hand. The nature of the cobbles depends very much upon the character and state of weathering of the original source rock. Eroded surfaces are strewn with these cobbles. Exposures along the highway from North Augusta to Belvedere, at Sweetwater Church, Warrenville quadrangle, contain a wide variety of cobble beds. On the Pine Log road near the Harmon store another profuse display of cobbles about the size of goose eggs is spread over the fields. In the southeast corner of the Harmon pit a thick deposit of cobbles extends from the surface down to the base of the Barnwell. The cobbles are included in a matrix of Barnwell clayey sands. It was impossible during the cursory examination to determine whether the channeling and deposition of gravel in the Barnwell occurred in a later stage of Barnwell time or during one of the Pleistocene cycles of erosion. If it can be definitely proved that these cobbles are of Barnwell origin, then much of the material now forming terrace deposits was in part contributed from the Barnwell as well as from later erosion in the Piedmont.

WARPING OF PIEDMONT SURFACE

The dominant structural movement of the Piedmont peneplain has been a gradual tilting to the southeast. Tilting probably began during Cretaceous time and was repeated later in minor amounts. The total rate of tilt is now approximately 25 feet to the mile. This ancient surface has also been subject to warping. A very prominent uplift was recognized by Stephenson in North Carolina, the axis of which trends approximately parallel with the Cape Fear River. A minor down-warped area which involves the Tuscaloosa formation is closely alined with the trend of the Savannah River and may be the cause of this trend. The productive clay bed on the south side of Horse Creek drops 100 feet within the 3 miles from the Immaculate mine southeastward to the McNamee mine. This bed is interpreted as a continuing series of interlocking clay lenses. The Piedmont surface north of Augusta shows this same trend. Also the slopes of the lower and upper surfaces of the Tuscaloosa as shown by exposures along the Georgia & Florida Railroad suggest a downwarping before Barnwell time. (See fig. 2.) The Barnwell formation appears also to be involved in this downwarp, although there can be less certainty on this point because of the indefinite character of the exposures.

EFFECTS OF SOIL CREEP

In South Carolina the unconsolidated Coastal Plain deposits slump or creep down the slopes of ravines and valleys. At places this overlapping blanket or mantle of material may extend a vertical distance of 100 feet or more below the base of the formation from which it is derived. This mantle ranges from 1 foot to 10 or 20 feet in thickness, depending upon the material, slope, length of period of accumulation, and other factors. It seriously interferes with prospecting operations, for it effectively conceals not only the outcrop of some clay beds but other beds in which clay seams might be expected. Where the top of the Tuscaloosa is exposed only at a considerable distance from a given locality, its position in the intervening area must be obtained by leveling. On the accompanying map of the Horse Creek and Aiken areas (pl. 2) the contacts of the formations are represented in accordance with data obtained in this way. Soil creep has been disregarded. Thus the Tuscaloosa-Barnwell contact has been outlined with a degree of accuracy commensurate with the conditions imposed by the nature of the geology. As no economic deposits of kaolin are known to exist in the Barnwell, explorations for clays should be confined to vertical intervals indicated by the altitude of the contact between the Barnwell and Tuscaloosa. Where the slope at any point along the contact is steep the belt available for prospecting will necessarily be narrow, but where the contact lies near the surface of a tableland of low relief a wide area is provided. Chance deposition of minable clay near the top of the Tuscaloosa and its exposure by later erosion have favored simple and extensive mining operations.

NATURE AND EXTENT OF SOUTH CAROLINA CLAYS

The kaolinitic clays of South Carolina are either residual, formed at their place of origin in the Piedmont of the northwestern half of the State, or sedimentary and confined to the Coastal Plain or southeastern half of the State. The Tuscaloosa formation is the main source of kaolinitic clays in the Coastal Plain. It forms the base of the Upper Cretaceous and lies directly upon the old eroded surface of the Piedmont. It crops out as a band stretching across the central portion of South Carolina with a northeast-southwest strike. The outcrop ranges in width from about 5 miles in the southwest to 50 miles in the northeast, the average width being 15 to 20 miles. (See pl. 1.)

GEOLOGIC CONDITIONS AFFECTING PROSPECTING

The season of the year in South Carolina best suited to geologic reconnaissance and prospecting is winter or early spring. The country is then more open, and visibility is increased tenfold over that of summer, when the luxuriant mat of shrubs and vines that covers the ground and the heavy growth of leaves upon the trees not only mask exposures that are easily visible from a distance in the spring but impede walking.

Soil creep in South Carolina tends to conceal the formations. The clay beds are lenticular and commonly end abruptly. The depth of a bed is important. Boring by hand 25 to 30 feet deep is hard and slow work, and the rate of boring decreases with depth. Good bodies of clay thus discovered at depths of 30 feet or more at a given place are of little present economic importance unless topography favors them elsewhere with less overburden. Thus the zone for prospecting is narrowed, and unless the geologic relations involved are understood needless expenditure of effort in selection of sites for testing follows.

The area of outcrop of the Tuscaloosa formation in South Carolina is cut into three parts—northeast, central, and southwest, by the Congaree and Wateree Rivers.

In all three areas the Tuscaloosa formation is composed almost wholly of sands and fine conglomerates, the clay beds and lenses being minor constituents. This is particularly true in the northeast segment, where, despite the great breadth of outcrop of the formation no economic clay beds have so far been reported. White clayey beds are also inconspicuous in this area, and it therefore seems likely that little clay was originally deposited there. The central segment contains deposits of good kaolin, but none are being worked now. The southwest segment contains an abundance of kaolin, and the only mines from which kaolin is now being shipped are located there. Most of the clay produced comes from Horse Creek and vicinity in Aiken County. Prospecting was confined to the southwest segment because of its greater promise of success.

METHODS OF PROSPECTING

Chance discovery.—Most of the discoveries of kaolin beds that have subsequently led to the development of mines of economic importance were made by chance. A reported observation in the woods by some Negro, the plowing of a field, or the digging of a well have been the initial causes for the opening up of more deposits than any direct method of search. Such a discovery occurred in 1934, when a farmer who had been living upon his land for over 50 years was forced to build a fence for protection from stray cattle and in digging holes for fence posts discovered that his property was underlain by a thick bed of good clay.

The primitive but still most satisfactory method of prospecting and sampling, especially where the clay beds lie at shallow depth, is to dig a pit. A pit or trench exposes a broad face showing the characteristics of the clay bed and affords more representative samples than can be obtained by any of the drilling methods. A stratum of clay balls would hardly be recognizable as such if prospected by the drill, but preliminary drilling is desirable if the clay bed lies at depth or if its position is in doubt.

Auger bit.—The auger-bit drill is perhaps the simplest, lightest, and most economical equipment for prospecting clays overlain by unconsolidated deposits. It consists of a common 1- to 1½-inch wood auger bit braised to a section of ½- to ¾-inch iron pipe, additional sections of pipe attachable by common couplings, and a tee and crossbar for handling. Fine dry sand or a wet hole is difficult to drill without casing. Clays of high plasticity are hard to part from the bottom of the hole, and it may require two men or even jacks to raise the bit after it has been screwed into the clay. One man can drill a shallow test, but two can do the work more easily and are essential where the tests go below 15 feet. In a wet hole, after setting casing, loose sands may be removed by a small improvised bailer. A tripod fitted with tackle over the hole aids the handling of casing, bailer, and rods. By casing to the top of the clay very clean samples may be taken cheaply by this method. The depth limit is arbitrary. Tests can be drilled to a depth of 100 feet or more by this method employing hand labor, but usually where depth is a factor modern mechanical methods are more satisfactory and economical.

Post-hole bit.—Drilling by means of the earth auger or post-hole bit is essentially the same as the method described above. This bit consists of two vertical curved blades cupped together at the bottom to form a basket and provide cutting edges. By the use of these bits larger holes are drilled and more sample is assured with apparently the same amount of effort. There is, however, greater likelihood of contamination and a less coherent sample is recovered. In hard ground where the application of pressure is necessary the blades tend to flatten and become less effective.

Two men are needed to operate the drill. The equipment consists of a suitable number of 4½-foot lengths of ¾-inch heavy iron pipe and couplings, a bit and tee handle, and two pipe wrenches.

The auger or post-hole bit can cut only 8 to 10 inches of ground before withdrawal for cleaning. Where the depth of the hole exceeds 15 to 20 feet the rods must generally be uncoupled to remove the bit. However, a universal coupling has been devised which makes it unnecessary to unscrew pipe joints. It consists of a double knuckle joint, which permits the rods to be folded back upon themselves, and a sleeve, which when dropped over the knuckle joints locks them in place. (See pl. 3.)

Sand bucket and wash drill.—Wells in coastal plain deposits are sometimes sunk by the sand bucket. The equipment consists of a tripod, pulley, rope, and sand bucket. Drive pipe usually follows the bucket. The sand bucket cannot be recommended as a tool for testing clays, but water wells drilled by this method afford useful data on the position and thickness of clay strata penetrated.

The simplest mechanical means for drilling wells is the wash drill, a small portable outfit including a gasoline engine belted to a snubbing pulley and a water pump. A fishtail bit lowered on rods washes down the hole. Short jabbing movements of the bit aid in breaking up new ground. The return water carries the cuttings to the surface, where samples may be caught. This method provides no better samples than the hand methods described above. In fact, the hand methods give more direct and more frequent recoveries from known depths.

Core barrel.—The core barrel, which provides a continuous and undistorted section of the clay, may be used to advantage with mechanical equipment. The type of core barrel or "drop bucket" in use in South Carolina for sampling clay consists of a 2-inch steel tube 12 to 15 inches long, with a 1½-inch inside diameter. The bit end is bell-mouthed or beveled, and the upper end is screwed to a socket fastened to the rods. After this bit is lowered to the clay it is driven in, and a section of clay is forced into the tube. Jacks are needed to raise the bit, because the adhesive and cohesive forces of moist clay are often such as to require a lifting force of several tons. If casing has been set to the top of the clay bed, a very clean and satisfactory core is recoverable. The sections are removed from the barrel by unscrewing it from the socket and forcing out the core with a plunger. Slight distortion occurs about the circumference of the clay but this part may be trimmed off, for observation of the undisturbed inside portion. Cavings may contaminate the upper end of the recovered core material. Cores so recovered provide the best samples, but too much reliance should not be placed upon an interpretation of a clay bed extrapolated from single cores. (See pp. 41, 46, and 51.)

Geophysical prospecting.—So far as is known no modern methods of geophysical prospecting have been applied to the search for clay in South Carolina. The nature of the Tuscaloosa formation would seem to make it particularly adaptable to prospecting by means of the electrical resistivity method, as the clay lenses lie in a matrix of loose sand. The coefficient of resistivity of the clay lenses must be considerably different from that of the enclosing body of sand, and therefore their detection below moderate thicknesses of overburden should prove easy. The character of lenses of clay so detected can be tested for quality only by drill sampling.

FIELD WORK

Field work in the summer of 1934 and spring of 1935 was confined principally to the part of the Tuscaloosa formation lying between Columbia, S. C., and Augusta, Ga. A review of the literature and a brief preliminary field investigation had shown that the Tuscaloosa contained far more clay west of the Congaree River than east of it. Accordingly in July, August, and September, 1934, 56 boring tests were made in Aiken, Edgefield, and Lexington Counties. These borings ranged in depth from a few feet to more than 40 feet, and the total footage drilled was 955 feet.

J. P. Nölting, Jr., served as field assistant during this period and had immediate charge of the drilling crew of two men. In the spring of 1935 the writer mapped and studied without assistance the clay beds of chief economic interest and through the kindness of the Huber Corporation was enabled to make a drill test through the Tuscaloosa formation. The results of the hand borings are tabulated on pages 52–61 of this report. Their locations are shown on plates 1 and 2 and figures 4–8.

RECORD OF PROSPECTING TESTS

Tests 1 to 4.—Four test holes were drilled by the post-hole method on the B. C. Weber property in the Oak Grove district, McTier Township, Aiken County, 1.2 miles east of the Wagener-Batesburg highway, on the road to the old Edisto clay mine, which is 2 miles farther east. (See pl. 1.) The work was done at the suggestion of Claude Carter, who, with Mr. Weber, stated that, in sinking a water well, 20 feet of good clay had been encountered 14 feet below the surface. The first test was made across the road from the house to a depth of 25 feet without encountering any indication of clay. A second test 120 feet north of the water well and topographically lower was drilled 25 feet without sign of clay. The third test, drilled 225 feet north of the house, encountered water and caved so badly that it was necessary to abandon the test at 11 feet without finding clay. The fourth hole was sunk 12 feet north of the water well to a depth of 20 feet without trace of clay, the bit samples showing pale-buff to brown sands. A pit dug 6 feet deep and tested with an auger bit to 17 feet some 280 feet east of the water well revealed no indication of clay.

From the character of the bit cuttings it is inferred that the tests were made in the Barnwell formation, the Tuscaloosa not having been encountered. Kaolinic clays may underlie the area tested, but the amount of overburden suggested by the borings would preclude economic development for the present.

Tests 5 to 56.—In the following table only those tests are described which yielded showings of clay.

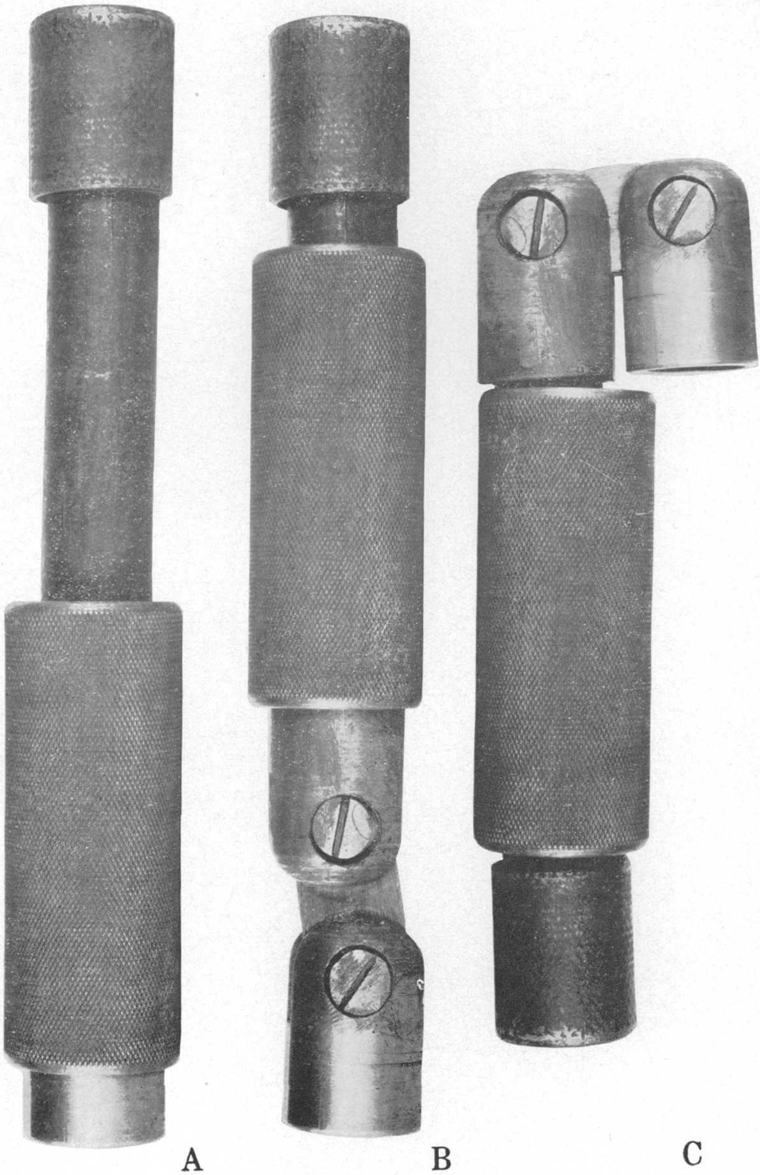
Record of tests 5 to 56

No.	Location	Description	Thickness Ft. in.	Depth Ft. in.	Remarks
5	East bank of Joyce Branch, 100 feet south of Two Notch Road, about 40 feet above creek, in Tuscaloosa formation, about 6 miles northeast of Aiken.	Soil, clayey, reddish, ¼-inch quartz pebbles	2 6	2 6	Clay crops out along banks of stream. Water at 13 feet. No valuable beds penetrated, all showings of clay being either off color or gritty. The 1 foot of clay exposed at the surface, in old washed-out road, dips 3° N. and is overlain by buff clayey sand.
		Clay, reddish, sandy, small angular quartz pebbles	2 6	5 0	
		Clay, reddish, sandy, with small angular quartz fragments	1 0	6 0	
		Clay, light-colored, sandy	6	6 6	
		Clay, dirty whitish, iron stains	6	7 0	
		Clay and clayey sand, light-colored, scattering of rounded quartz pebbles.	3 0	10 0	
		Clay, gritty, white, iron-stained	4 0	14 0	
		Sand, yellow, clayey	3 0	17 0	
6	Lee Arthur property, 6 miles northeast of Aiken and north of Two Notch (New Holland) Road, in Wilkins Hollow at spring site.	Clay, dry, crumbly, yellowish, little grit	5 0	5 0	The clay is tough and undoubtedly a prospective rubber clay. It has potential commercial value if it grades into gritless clay of improved color. Drainage conditions excellent. Overburden not excessive.
		Clay, crumbly, little grit, weak buff color	3 0	8 0	
		Clay, whitish, slightly gritty, moist	1 6	9 0	
		Clay, yellowish, gritty	3	9 3	
		Clay, white, very little grit, slightly moist	9	10 0	
		Clay, yellowish, little grit, slightly moist	2 6	12 6	
		Clay, brown-stained, gritty, slightly moist	1 0	13 6	
		Sand, yellow, clayey, etc	5 0	18 6	
7	100 feet S. 35° W. of No. 6	Soil, sandy, loamy	3 0	3 0	Show of water at 6 feet, whitish clay balls at 9 feet. Drilling stopped at 11 feet because of water.
		Clay, reddish; lighter-colored with depth	8 0	11 0	
8	50 feet S. 65° E. of No. 7	Loam, sandy, reddish	10 0	10 0	Loam becomes clayey downward. Water at 11 feet. Clay bed has been truncated by erosion and further stained by weathering. The 10 feet of cover represents an overwash of late terrace deposits.
		Clay, reddish yellow, sandy	2 0	12 0	
		Clay, whitish, buff to reddish stain, gritty	3 6	15 6	
		Clay, yellowish, sandy, micaceous	1 6	17 0	
		Sand, yellowish, coarse-grained	1 6	18 6	
9	80 feet N. 12° E. of No. 6	Loam, red, sandy	4 0	4 0	
		Clay, buff, sandy, reddish and white splotches, gritty with angular quartz grains.	2 6	6 6	
		Clay, reddish, with buff and whitish inclusions, sandy; becomes lighter-colored downward.	4 6	11 0	
		Clay, whitish, crumbly; has reddish stains; slightly sandy and micaceous.	6	11 6	
		Clay, whitish, crumbly rubber clay, little coarse grit	6	12 0	
		Clay, whitish, crumbly, buff stains and gritty	1 6	13 6	
		Sand, yellow	6	14 0	
		Sand, white	1 0	15 0	
10	On Chapin Hill, 50 feet north of center of Two Notch Road and 0.6 mile northeast of Welcome Traveler Church.	Loam, brown, sandy	1 0	1 0	This clay bed undoubtedly correlative with that of No. 6. Area between and adjacent to these tests probably underlain by clay beds of possible commercial value for rubber industry.
		Sand, coarse, quartz	1 0	2 0	
		Clay, white, very little grit, red and yellow stains	3 0	6 0	
		Clay, white, grit-free, pale buff, reddish stains	6	6 6	
		Clay, light buff, very little grit, yellow stains; becomes whiter downward.	5 0	11 6	

		Clay, buff, little grit, dry, crumbly	5	6	17	0	
		Clay, light buff, little grit, crumbly; has darker-buff stains	3	0	20	0	
		Clay, light buff, gritty, crumbly, dry	4	0	24	0	
		Clay, buff, crumbly, slight gritty, yellowish stains	5	0	29	0	
		Clay, yellow, gritty		6	29	6	
		Clay, white, gritty, yellowish stains	3	6	33	0	
		Sand, yellow, clayey					
11	On west bank of South Fork of Edisto River and on south side of Two Notch Road.	Sand, yellowish	2	0	2	0	Clay not exposed but damp horizon noted on highway. Water at 3½ feet.
		Sand, brown	3	0	5	0	
		Clay, variegated dark brown to grayish, sandy	1	0	6	0	
		Clay, gravelly	1	0	7	0	
12	On Jud Brodie property, 11.7 miles east of Aiken on New Holland Road and 1.1 miles northwest of intersection with Foxtown Road.	Sand, red	1	0	1	0	East side of road. Clay crops out in ditches. Water at about 4½ feet. Test abandoned with 8 feet water in hole.
		Clay, gravelly, reddish, white clay balls		6	1	6	
		Sand, clayey, coarse, brown		6	2	0	
		Sand, clayey, lavender, coarse, micaceous	1	0	3	0	
		Sand, coarse, brown, some red	2	0	5	0	
		Sand, lavender, white clay balls, finer downward	1	6	6	6	
		Clay, light, mottled, micaceous, gritty	1	6	8	0	
13	In ditch by road, 60 feet N. 50° W. of No. 12	Sand, red	3	0	3	0	
		Clay, whitish buff, sandy		6	3	6	
		Clay, variegated, sandy	2	0	5	6	
		Sand, lavender, clayey, coarse, etc	6	0	11	6	
14	70 feet S. 35° E. of No. 12	Sand, coarse, brown, partly cemented	1	6	1	6	
		Sand, red, coarse, clay fragments		6	2	0	
		Sand, purple, clay fragments		3	2	3	
		Clay, variegated, gritty	2	9	5	0	
		Clay, light buff, little grit	1	0	6	0	
		Clay, light buff, brown-stained, gritty	1	0	7	0	
		Clay, variegated, gritty	1	3	8	3	
		Clay, light buff, gritty	1	0	9	3	
		Clay, light buff, sandy	1	3	10	6	
		Clay, variegated, sandy, micaceous		6	11	0	
		Sand, buff, coarse, clayey	1	6	12	6	
15	60 feet S. 60° W. of Foxtown road, 0.7 mile north of intersection with New Holland road.	Loam, brown, sandy	4	0	4	0	Water at 16 feet.
		Sand, buff, clayey, brown stained	1	0	5	0	
		Sand buff to brown, coarse, clayey, micaceous	4	0	9	0	
		Clay, reddish, sandy, micaceous, white clay balls	1	6	10	6	
		Clay, variegated, gritty, micaceous	1	6	12	0	
		Clay, whitish, gritty, micaceous		6	12	6	
		Clay, whitish, gritty, stained red and brown	1	6	14	0	
		Sand, whitish, clayey, stained buff		6	14	6	
		Sand, pinkish, clayey, micaceous	1	0	15	6	
		Clay, lavender, sandy, micaceous		6	16	0	
		Sand, whitish, clayey, micaceous	1	6	17	6	

Record of tests 5 to 56—Continued

No.	Location	Description	Thickness Ft.	Thickness in.	Depth Ft.	Depth in.	Remarks
16	3.2 miles northeast of Aiken on old Columbia (Two Notch) road, 0.3 mile beyond junction of New Bridge road, in ditch on south side.	Gravel, coarse		9		9	Thickness of clay bed 22 feet 3 inches.
		Clay, light buff, gritty		3	1	0	
		Clay, light buff, stained, gritty	2	0	3	0	
		Clay, buff, gritty, crumbly	1	0	4	0	
		Clay, buff, hard, dry, brown-stained, little grit	3	0	7	0	
		Clay, buff, some grit		6	7	6	
		Clay, whitish, hard, dry, little grit	1	0	8	6	
		Clay, light buff, little grit	3	6	12	0	
		Clay, light buff, brown-stained, some grit	5	0	17	0	
		Clay, light buff, brown-stained, gritty	1	6	18	6	
		Clay, buff, gritty	4	6	23	0	
		Clay, buff, sandy, micaceous		6	23	6	
		Sand, yellow, clayey	1	0	24	6	
18	On Gorgas Sanders property, south side of U. S. Highway 1, near Monetta, Aiken County, 1,200 feet east of Marcellus School.	Sand, red, coarse	3	0	3	0	
		Clay, buff, sandy		6	3	6	
		Sand, red, clayey, coarse		3	3	9	
		Clay, gray, gritty, iron stains	1	3	5	0	
		Clay, white, very gritty, iron stains	2	0	7	0	
		Clay, whitish to reddish, very little grit		3	7	3	
		Clay, white, little grit, iron stains	2	0	9	3	
		Clay, white, gritty, stained	1	3	10	6	
		Sand, red, with clay fragments		3	10	9	
19	80 feet N. 55° W. of No. 18	Sand, brown	3	0	3	0	
		Clay, buff, gritty		6	3	6	
		Sand, reddish, coarse, white clay fragments	2	0	5	6	
		Clay, white, sandy, iron-stained		6	6	0	
		Clay, buff, sandy		6	6	6	
		Sand, pinkish, clayey, etc	1	9	8	3	
20	130 feet west of No. 18	Clay, red, sandy	9	6	9	6	Pits dug through clay after tests 18–20 were drilled on Sanders property showed that much of it is in balls ranging in size from that of a base ball to that of a watermelon, and varying in texture and grit content. Most of the clay is white. Interstices between clay balls are filled with loose brown to red sand which mixes with clay during drilling. Samples therefore do not show true nature of the clay.
		Clay, white, coarse, sandy, iron stains		6	10	0	
		Sand, red, clayey		6	10	6	
		Clay, white, very little grit	2	6	13	0	
		Clay, light buff, little grit	1	0	14	0	
		Clay, whitish, little grit, iron stains	1	0	15	0	
		Clay, yellowish, admixed white clay and grit		3	15	3	
		Clay, whitish, slightly gritty	2	6	17	9	
		Clay, gray, gritty	3	0	20	9	
		Clay, gray, sandy, iron-stained	1	0	21	9	
		Sand, variegated, red dominant	1	9	23	6	



A B C

DRILL-ROD KNUCKLE JOINT.

A, Knuckle joint with sleeve in place ready for drilling. The sleeve automatically falls into place and locks the rods when both sections are straightened and lowered into the hole.
B, Sleeve raised, exposing knuckle joints and permitting upper section of the rods to be folded back.
C, Upper section folded back into position against the lower section for removal of the bit from the test hole. This joint makes it unnecessary to disconnect the rods in drilling deep test holes.

21	About half a mile south of U. S. Highway 1, opposite Gorgas Sanders place. (See test 18).	Sand, brown	1	6	1	6	
		Sand, reddish brown	3	0	4	6	
		Sand, yellowish brown with clay balls	2	0	6	6	
		Sand, reddish, with clay balls	3	0	9	6	
		Sand, reddish, clayey	4	6	14	0	
		Clay, white, sandy, coarse, iron stains	1	0	15	0	
		Clay, white, sandy, micaceous, iron stains		6	15	6	
		Sand, varicolored, and clay, buff		6	16	0	
		Clay, gray, gritty, iron stains	1	0	17	0	
		Clay, buff, gritty	1	6	18	6	
		Clay, white, sandy		6	19	0	
		Clay, buff, gritty, iron-stained	1	6	20	6	
		Clay, pinkish, sandy, micaceous	1	0	21	6	
		Clay, varicolored, sandy, micaceous	1	0	22	6	
		Sand, buff, micaceous, clayey.					
22	About 600 feet west of John Rainey house, west side of U. S. Highway 1, 1.2 miles north of Shaw Creek and 5 miles northeast of Aiken.	Sand, yellow	3	0	3	0	Water at 8 feet. Test abandoned at 10 feet because of water.
		Sand, reddish, clayey	1	6	4	6	
		Sand, brownish, clayey	3	0	7	6	
		Sand, yellowish to brownish, clayey		6	8	0	
		Clay, white, yellow stains, gritty	2	0	10	0	
23	170 feet south of No. 22	Sand, brownish, clayey	5	0	5	0	
		Sand, reddish, clayey	3	6	8	6	
		Sand, brownish, clayey		3	8	9	
		Clay, variegated, little grit, dry, crumbly	1	6	10	3	
		Clay, buff, little grit, iron-stained	7	0	17	3	
		Clay, buff to white, gritty, iron-stained	1	6	18	9	
		Sand, yellowish, micaceous, clayey, etc	3	3	22	0	
		Sand, yellow					
25	250 feet S. 15° E. of No. 24 which is 460 feet S. 10° W. of No. 23.	Sand, brown	4	0	4	0	Quartz pebbles at 16 feet, white clay fragments at 18 feet.
		Sand, yellow, clayey	2	0	6	0	
		Sand, reddish, clayey	3	6	9	6	
		Sand, yellowish red, clayey	1	0	10	6	
		Sand, reddish, clayey	4	0	14	6	
		Sand, red, clayey, coarse	7	0	21	6	
		Clay, whitish to buff, sandy		6	22	0	
		Conglomerate, coarse, brown		3	22	3	
28	About a quarter of a mile N. 80° W. of No. 27. (No. 26 is half a mile west and north of No. 22, on west side of ravine, and No. 27 is 420 ft. S., 30° W. of No. 26.)	Sand, buff	3	0	3	0	White sandy clay balls at 5½ feet. Quartz pebbles at 17 feet.
		Sand, reddish brown	3	0	6	0	
		Sand, brownish, clayey with whitish clay balls	3	0	9	0	
		Sand, reddish, clayey	5	0	14	0	
		Clay, variegated, sandy	2	0	16	0	
		Sand, reddish clayey, and conglomerate	1	0	17	0	
29	About ½ mile N. 25° W. of No. 28, by a clay prospect.	Sand, red	1	0	1	0	
		Clay seam becomes a variegated sandy clay					
30	East side U. S. Highway No. 1, about ¼ mile south of Shaw Creek and 4 miles north of Aiken.	Gravel	1	6	1	6	
		Clay, buff, variegated, gritty	1	0	2	6	
		Sand, brown, yellow, white, etc., clayey in part	8	6	11	0	

Record of tests 5 to 56—Continued

No.	Location	Description	Thickness	Depth	Remarks
			Ft. in.	*Ft. in.*	
31	40 feet north of old Augusta road, 1½ miles west of Aiken, 440 feet west of R. R. crossing top of bank.	Sand, brown, clayey	3 0	3 0	
		Sand, pinkish, clayey	1 6	4 6	
		Clay, variegated, sandy, with white clay fragments	2 6	7 0	
		Clay, white, gritty, iron stains	1 0	8 0	
		Clay, variegated, gritty	3	8 3	
		Sand, brown, whitish, clayey in part	9 9	18 0	
32	On U. S. Highway 1, 50 feet N. 15° E. of No. 30.	Sand and gravel	6	6	Clay lens exposed at surface pinches out downward.
33	1½ miles west of the Silver Bluff road, 11 miles south of Aiken, east bank of Town Creek.	Sand, brown	1 6	1 6	
		Clay, brown, gritty	6	2 0	
		Clay, purple, gritty	6	2 6	
		Clay, brown, gritty	6	3 0	
		Sand, different colors, more or less clayey	6	3 6	
			7 0	10 6	
34	¼ mile northeast of Little Holley Creek and south of Tory Trail, about 2½ miles west of intersection with Whiskey Road.	Soil, brown, sandy	6	6	
		Sand, reddish brown	3 6	4 0	
		Sand, dark brown clayey	3	4 3	
		Clay, buff, iron stained, gritty, crumbly, dry	4 0	8 3	
		Clay, pinkish, sandy	2 3	10 6	
		Sand, yellowish brown	6	11 0	
		Sand, pale pinkish, clayey	6	11 6	
		Clay, pinkish to buff, little grit	3 6	15 0	
		Clay, buff, gritty	1 0	16 0	
		Sand, buff, clayey	2 0	18 0	
		Clay, black, carbonaceous	6	18 6	
		Clay, brownish to black, sandy	6 0	24 6	
		Clay, buff, gritty	3 6	28 0	
		Sand, brown	1 0	29 0	
35	About 300 feet S. 20° W. of No. 34				Test 15 feet deep, mostly sand; few poor showings of clayey material, clay balls at about 12 feet.
36	About 300 feet N. 60° W. of No. 35				Test 18½ feet deep, mostly sand, 3 inches of brown gritty clay at about 8 feet.
37	200 feet S. 80° E. of No. 34				Test 20 feet deep, all clayey sand, quartz pebbles near bottom.

38	About 4 miles east of Aiken on north slope of Redds Branch, south side of road about 1 mile east of Redds Branch School and 1 mile southwest of Wright's mill, on O. L. Courtney property.	Sand, buff	2	6	2	6	Water at 10 feet.
		Sand, yellowish brown, clayey	1	6	4	0	
		Sand, brownish to white, clayey, coarse	4	0	8	0	
		Sand, reddish, clayey	2	0	10	0	
		Clay, white, gritty, iron-stained	2	0	12	0	
		Clay, white, gritty	3	0	15	0	
		Clay, white, little grit, iron-stained	1	6	16	6	
		Clay, creamy, little grit	3	0	19	6	
		Clay, white, gritty		6	20	0	
		Clay, white, slightly gritty	1	0	21	0	
		Clay, white, gritty, iron-stained	1	0	22	0	
		Clay, white, sandy, iron-stained	2	0	24	0	
		Clay, yellowish-brown, micaceous, gritty, white clay fragments	1	0	25	0	
39	140 feet S. 16° W. of No. 38	Sand, yellowish-brown, clayey	3	0	3	0	Water at 4½ feet.
		Sand, gray	1	0	4	0	
		Clay, gray, sandy	2	0	6	0	
		Clay, white, gritty	1	0	7	0	
		Clay, white, iron-stained, slightly gritty	2	0	9	0	
		Sand, yellow, fine, white gritty clay fragments		6	9	6	
		Clay, buff, iron-stained, gritty	3	6	13	0	
		Clay, white, gritty	2	0	15	0	
		Clay, white, iron-stained, gritty	4	0	19	0	
		Clay, white, sandy, micaceous	2	6	21	6	
		Clay, buff, micaceous, sandy		6	22	0	
		Clay, light buff, little grit	1	0	23	0	
40	80 feet S. 5° W. of No. 39	Soil, dark, loamy	2	0	2	0	Water at 5 feet.
		Clay, grayish brown, sandy	1	6	3	6	
		Clay, reddish brown, sandy	1	0	4	6	
		Sand, gray, clayey	2	0	6	6	
		Clay, dark gray to black, carbonaceous	1	6	8	0	
		Clay, gray, sandy to pebbly	1	6	9	6	
		Clay, gray, sandy	1	0	10	6	
		Clay, light gray, micaceous, gritty	8	0	18	6	
		Clay, light gray to creamy, micaceous, gritty		6	9	0	
		Clay, yellowish, gritty		3	19	3	
		Clay, grayish to creamy, sandy, micaceous	1	3	20	6	
		Sand, yellow					
41	Crest of divide between Horse Creek and Little Horse Creek, Graniteville road, southwest side.	Sand, brown	3	6	3	6	
		Sand, brown, clayey: pebbles at 4 feet	1	6	5	0	
		Sand, reddish brown, clayey	1	0	6	0	
		Clay, white, sandy, red iron-bearing streaks	2	0	8	0	
		Clay, white, sandy, micaceous	2	0	10	0	
		Sand, yellow, white, micaceous, etc	8	6	18	6	
42	60 feet north of No. 41	Clay, exposed	4	0			
		Clay, buff, slightly gritty, iron-stained	2	0	2	0	
		Clay, pinkish, slightly gritty	1	0	3	0	
		Clay, whitish to pinkish, gritty		3	3	3	
		Sand, whitish to brownish, micaceous, clayey		9	4	0	

Record of tests 5 to 56—Continued

No.	Location	Description	Thickness		Depth		Remarks
			Ft.	*in.*	*Ft.*	*in.*	
43	40 feet west of U. S. Highway 25 (Augusta-Trenton), on north bank of Horse Creek, about 4 miles south of Edgefield Junction.	Sand, whitish, clayey, iron-stained	2	0	2	0	Water at about 7 feet.
		Clay, light yellow, gritty, brown sandy streaks	3	0	5	0	
		Clay, light buff to whitish, gritty	1	0	6	0	
		Clay, yellowish, sandy		3	6	3	
		Sand, yellow, white, fine and coarse		9	7	0	
44	Ravine north of Southern Railway track west of Highland Park Golf Clubhouse, Aiken.	Clay, gray, buff, white, gritty, variably iron-stained. Exposed in ravine.	18	0	-----		Exposed clay, truncated on west.
		Clay, buff, slightly gritty, iron-stained	3	6	3	6	
		Clay, buff, gritty	1	0	4	6	
		Clay, yellowish, gritty		6	5	0	
		Sand, brownish, clayey	2	0	7	0	
		Clay, gray, gritty, micaceous	2	0	9	0	
		Sand, brownish, whitish, micaceous, etc		6	9	6	
45	South side of U. S. Highway 1, 300 feet west of junction of Leesville-Batesburg road, near bridge over Southern Ry., Lexington County.	Sand, brown	1	0	1	0	
		Sand, dark brown		6	1	6	
		Sand, light brown	5	0	6	6	
		Sand, reddish brown, with clay fragments and gravel	2	6	9	0	
		Clay, gray, gritty		6	9	6	
		Clay, gray, iron-stained	1	0	10	6	
		Clay, purple, gritty	2	0	12	6	
		Clay, gray, gritty	2	0	14	6	
		Clay, red stained, very gritty		6	15	0	
		Clay, yellow, sandy		3	15	3	
		Clay, gray, gritty	1	0	16	3	
		Clay, purple, gritty		3	16	6	
		Clay, brown, sandy		3	16	9	
		Clay, gray, gritty, micaceous	1	3	18	0	
		Sand, micaceous, clayey	1	6	19	6	
46	About 250 yards west of Wilson (Hendrick's) Pond, east bank of Town Creek, between Silver Bluff and Pine Log roads.	Soil, brown, loamy		3		3	
		Sand, brown, clayey	1	3	1	6	
		Clay, buff, slightly gritty, iron-stained	7	6	9	0	
		Clay, gray, very little grit, slightly stained	3	0	12	0	
		Clay, buff, slightly stained, little grit, increasing downward	10	0	22	0	
		Clay, grayish, slightly gritty	1	0	23	0	
		Clay, grayish, slightly iron-stained, little grit		6	23	6	
		Clay, dark gray, slightly gritty	1	0	24	6	
		Clay, grayish, slightly gritty	5	0	29	6	
		Clay, buff, gritty, iron-stained	2	6	32	0	
		Clay, buff, sandy	9	0	41	0	

47	50 feet southeast of road and 2 miles north of Plato School, east of Trenton, Edgefield County.	Sand, brown, clayey	1	0	1	0	Water at 14 feet.
		Sand, pinkish, clayey	4	0	5	0	
		Clay, buff, iron-stained, gritty	1	6	6	6	
		Clay, buff, gritty, yellow sandy streaks	1	3	7	9	
		Clay, buff, stained, gritty	2	0	9	9	
		Clay, varicolored, sandy, deeply iron-stained	5	3	15	0	
		Sand, brown, reddish, buff, micaceous					
48	6 miles north of Aiken, 1 mile east of Edgefield road, on west bank of Shaw Creek, about 1 mile south of Aiken waterworks.	Sand, brown, fine, clayey	1	6	1	6	Water at 8 feet. Ironstone conglomerate bed 1 foot 2 inches thick at about 8 feet.
		Sand, dark brown, fine, clayey		3	1	9	
		Sand, yellow, fine clayey, micaceous	3	3	5	0	
		Sand, brown, occasional clay lump	4	0	9	0	
		Clay, buff to white, sandy		3	9	3	
		Clay, purple	1	9	11	0	
49	40 feet N. 50° E. of No. 48	Sand, dark brown, clayey	1	6	1	6	
		Ironstone as at No. 48		3	1	9	
		Clay, buff to white, sandy		3	2	0	
		Clay, purplish variegated, gritty	2	6	4	6	
		Clay, grayish to brownish white, gritty	1	0	5	6	
		Clay, grayish purple, sandy	1	0	6	6	
		Clay, purplish, variegated, gritty	1	6	8	0	
		Clay, buff, gritty, slight iron stain	1	0	9	0	
		Clay, buff to white, slightly gritty and iron-stained		3	9	3	
		Clay, pale purplish, slightly gritty, iron-stained		9	10	0	
		Clay, pinkish creamy with darker purplish stains	2	0	12	0	
		Clay, purplish creamy	5	0	17	0	
		Clay, pale purplish creamy, gritty, micaceous	4	0	21	0	
		Clay, whitish, micaceous, purple stains	1	0	22	0	
		Clay, whitish, buff, purple-stained, little grit	1	0	23	0	
		Clay, whitish, purple-stained, sandy, micaceous		6	23	6	
		Clay, buff, slightly gritty	9	0	32	6	
		Clay, purplish, gritty	1	0	33	6	
		Clay, yellowish, sandy, micaceous	3	0	36	6	
		Sand, yellow		6	37	0	
50	At base of overburden at northeast corner of Edisto Kaolin Co.'s mine, about 10 miles northeast of Aiken. (See fig. 4.)	Sand, brown	2	0	2	0	
		Clay, white, slightly gritty, iron stains	1	0	3	0	
		Clay, white, no grit, little iron stain	2	0	5	0	
		Clay, white, no grit, iron-stained		3	5	3	
		Clay, white, no grit		6	5	9	
		Clay, white, no grit, iron stains	1	0	6	9	
		Clay, light buff, no grit, iron-stained		6	7	3	
		Clay, buff, no grit	2	3	9	6	
		Clay, white, no grit, iron-stained		6	10	0	
		Clay, white, very little iron stain	1	6	11	6	
		Clay, white, no grit, iron-stained	2	6	14	0	
		Clay, light purplish, micaceous, no grit	2	0	16	0	
		Clay, light purplish, micaceous, gritty	1	6	17	6	
		Clay, purplish, gritty, micaceous	3	0	20	6	
		Clay, buff, iron-stained, gritty, micaceous		6	21	0	
		Clay, purplish, gritty, micaceous	1	0	22	0	
		Sand, yellow, micaceous	1	0	23	0	

Record of tests 5 to 56—Continued

No.	Location	Description	Thickness	Depth	Remarks
			Ft. in.	*Ft. in.*	
51	At north-central face of Edisto Kaolin Co.'s mine. (See fig. 4.)	Sand, yellow, iron concretions	6	6	
		Clay, gray, iron stains, no grit	2 6	3 0	
		Clay, gray, no grit	1 0	4 0	
		Clay, gray, no grit, iron stains	6	4 6	
		Clay, buff, no grit	1 0	5 6	
		Clay, pale buff, no grit	2 6	8 0	
		Clay, gray, no grit, very little iron stain	6	8 6	
		Clay, pinkish, no grit	3	8 9	
		Clay, pinkish to buff, iron stains, no grit	6	9 3	
		Clay, buff, no grit, iron stains	3	9 6	
		Clay, purplish, no grit, micaceous, white clay fragments	1 0	10 6	
		Clay, grayish lavender, slightly gritty	1 9	12 3	
		Clay, purplish, variegated, gritty	1 0	13 3	
		Clay, purplish to yellow, sandy	1 0	14 3	
		Clay, purplish, sandy	6	14 9	
		Sand, variegated, clayey, micaceous, etc	1 9	16 6	
52	On micaceous seam in Edisto Kaolin Co.'s mine. (See fig. 4.)	Clay, grayish, micaceous, iron-stained, no grit	6	6	
		Clay, grayish, micaceous, iron streaks	3 0	3 6	
		Clay, grayish, iron-stained, micaceous, no grit	3	3 9	
		Clay, gray, iron-stained, no grit	2 9	6 6	
		Clay, gray, no grit, very little iron stain	6	7 0	
		Clay, grayish to pinkish, no grit	1 0	8 0	
		Clay, pale buff, slightly micaceous	1 0	9 0	
		Clay, buff to gray, iron-stained, micaceous, very little grit	6	9 6	
		Clay, variegated, gritty, micaceous	2 0	11 6	
		Clay, variegated, sandy, micaceous	1 0	12 6	
		Sand, purplish, micaceous, clayey	2 6	15 0	
53	Edisto Kaolin Co.'s mine, about 120 feet southwest of No. 52, on top of bank. (See fig. 4.)	Clay, buff, iron-stained, no grit	9 9	9 9	
		Clay, gray, slightly iron-stained, no grit	1 0	10 9	
		Clay, buff, iron-stained, slightly micaceous and gritty	1 3	12 0	
		Clay, variegated, purplish, no grit, slightly micaceous	1 6	13 6	
		Clay, variegated, purplish, gritty, slightly micaceous	6	14 0	
		Clay, variegated, sandy, micaceous	1 0	15 0	
		Sand, variegated, micaceous, purplish, etc	3 0	18 0	
54	Top of bank, 175 feet south of No. 53, Edisto Kaolin Co.'s mine. (See fig. 4.)	Clay, grayish white, no grit, occasional inclusions of iron oxide	4 0	4 0	
		Clay, buff, no grit	6	4 6	
		Clay, grayish, no grit	2 6	7 0	
		Clay, pale buff, no grit, occasional inclusions of iron oxide	2 0	9 0	
		Clay, grayish, no grit, iron stains	6	9 6	
		Clay, buff, gritty	1 6	11 0	
		Clay, purplish, variegated, micaceous, gritty	1 0	12 0	

55	Northwest corner of Morris clay pit of Southeastern Clay Co., about 4.5 miles northwest of Aiken. (See pl. 2.)	Clay, white, exposed in mine	5	0		
		Clay, grayish white to pinkish, slightly gritty and micaceous		6		6
		Clay, brown, micaceous, sandy streaks		6	1	0
		Sand, brown	7	0	8	0
56	Immaculate Kaolin Co.'s clay mine. (See pl. 2.)	Clay, white to buff, iron-stained, no grit	4	0	4	0
		Clay, pale purplish, no grit	10	0	14	0
		Clay, white, no grit	2	0	16	0
		Clay, pale buff, no grit	1	0	17	0
		Clay, buff, no grit	3	0	20	0
		Clay, dark brown to black, carbonaceous	3	0	23	0
		Clay, buff, no grit	4	0	27	0
		Sand	3	0	30	0

Summary of prospecting tests.—Of the 56 prospecting tests 3 were less than 5 feet deep, 9 were between 5 and 10 feet, 11 from 10 to 15 feet, 15 from 15 to 20 feet, 12 from 20 to 25 feet, 3 from 25 to 30 feet, and 3 more than 30 feet. Of the total, 10 were bottomed in clay and presumably might have yielded greater thicknesses of that material; 45 were bottomed in sand, and 1 in conglomerate. Twenty of the tests revealed less than 2 feet of clay, 8 showed thicknesses between 2 and 5 feet, 12 between 5 and 10 feet, 5 between 10 and 15 feet, 4 between 15 and 20 feet, and 7 more than 20 feet. Seven of the tests were made in active or old clay pits. Much of the clay exposed in these tests was gritty and more or less colored. A few give promise of suitability for use in the rubber industry, especially Nos. 6 and 10.

CERAMIC TESTS

SELECTION OF SAMPLES

In order to provide information that would serve as a basis for comparison of the ceramic characteristics of different South Carolina kaolins, a suite of samples was taken from the more important and accessible sources of clay and was sent to the Ceramics Department of the Georgia School of Technology at Atlanta, Ga., Prof. A. V. Henry in charge, for test. In all 31 samples were collected, 3 of which (A, B, C, pl. 2) represent residual clays from the Piedmont of Edgefield County, and the remaining 28 provide a representative cross section of the Tuscaloosa clay deposits of South Carolina. They were intentionally taken from outcrops and mine faces rather than from drilled samples, so that the localities may be reexamined and resampled at any time without undue inconvenience.

In selecting samples for test precautions were taken to obtain average representative material without special selection or hand sorting. The samples ranged in weight from 35 to 90 pounds.

A description of the procedure followed in running tests on the clays under the direction of Professor Henry is given below, together with the test data supplied by him for the different samples.

PROCEDURE

Thirty-one samples of South Carolina kaolin were received at the laboratory. These (with the exception of Piedmont Nos. 1, 2, and 3) were ground in a roll crusher to pass 16 mesh. The Piedmont clays, owing to coarse accessory minerals, were ground to pass coarser screens (Piedmont No. 1 through 4 mesh and Nos. 2 and 3 through 8 mesh).

Ten bars of each clay, 1⅛ inches in diameter and 6 inches long were formed in an extrusometer (cylinder with plunger and tapered die). Shrinkage, water of plasticity, and dry modulus of rupture were determined from these bars.

Slaking was measured on a crude lump of clay cut to a cube approximately 5 grams in weight. Settling was noted on the same sample shaken in a test tube with 900 percent of water.

A 200 gram sample of each clay was disintegrated in a jar mill for 1 hour with rubber balls, using 800 percent of water. The sample was transferred to a standard 200-mesh screen and washed with a fine spray of water. The residue was dried, weighed, and reported as percent of original sample. In describing the residue the letters A and T were suffixed to a mineral to denote abundance and trace respectively.

The suspension containing the fines was evaporated to dryness and the clay ground to pass 20 mesh. A part of this was mixed with water and pressed into a plaster mold forming a disk 2½ inches in diameter and three-eighths inch thick. This was removed from the mold after formation and marked for shrinkage.

A successful whiteware body composition was chosen, and the Georgia kaolin content replaced by each of the sample clays. This gave the following composition:

	Original whiteware (percent)	Test whiteware (percent)
G*1 (hard kaolin)	10	
Sandersville, Ga.	14	
Test clay (South Carolina)		24
Lamonti (North Carolina primary kaolin)	9	9
Florida plastic kaolin	7	7
Kentucky O. M. No. 4 (ball clay)	9	9
North Carolina hard spar	20	20
Flint	31	31
	100	100

The base of the whiteware was ground as a thin slip and the test clay added with half an hour blunging. This slip was poured into plaster molds and when sufficiently dry was pressed into disks, as was done with the pure clay. Disks of both clay and the whiteware body were fired in a gas-fired kiln in saggers. The kiln was fired to cone 9 (in sagger) in 21 hours with a 5-hour soaking period. All shrinkages were calculated on the plastic basis.

The properties of the original whiteware body which contained Georgia kaolin are given below. Those of the South Carolina clays tested are given in the following descriptions of the respective samples.

Clay disks. G* 1: Sandersville as 1:1.4. Drying shrinkage, 3.2 percent; drying behavior, no cracks; firing shrinkage, 11.6 percent; firing behavior, no cracks.

Whiteware disks.—Original body as noted in procedure. Drying shrinkage, 2.8 percent at cone 9; firing shrinkage, 9.0 percent; absorption, 4.8 percent; fired appearance, good white color.

TESTS

The following list shows the locations from which the 31 samples used for ceramic tests were obtained. (See pl. 2.)

1. United Clay Mines Corporation, Daniels pit.
2. Killian pit, near Columbia.
3, 4. Lexington Clay Mines, Inc., Edmund.
5, 6. Edisto Kaolin Co., eastern Aiken County.
7. Reddy test pit, eastern Aiken County.
8. Southeastern Clay Co., Piper pit.
9. Southeastern Clay Co., Gunter pit.
10. Southeastern Clay Co., Morris pit.
11. Southeastern Clay Co., China Spring pit.
12. Toole pit, Bridge Creek.
13. Huber Corporation, Graniteville mine.
14. Huber Corporation, Richardson pit.
15. Huber Corporation, Harrigal pit.
16. Huber Corporation, clay balls, Harrigal pit.
17, 18. Immaculate Kaolin Co., pit.
19. Immaculate Kaolin Co., drill test in pit.
20. North American Clay Co., Continental pit.
21–23. J. R. Parker, Chicora pit.
24. North American Clay Co., Harmon pit.
25. Old Parker pit.
26. Huber Corporation, Alum pit.
27. South Carolina Clay Co., mine.
28. North American Clay Co., McNamee mine.
29. Piedmont No. 1, Warrenville quadrangle.
30. Piedmont No. 2.
31. Piedmont No. 3.

Sample 1.—The United Clay Mines Corporation, of Trenton, N. J., was at one time known as the Interstate Clay Co. and the G. B. Daniels Kaolin Co., Horrell Hill, Richland County, 12 miles southeast of Columbia, S. C. The sample was taken from the upper 2 feet of the 8- to 10-foot clay bed in the north wall of the clay pit, from which the incline ascends to the clay plant. The lower 6 to 8 feet of clay is now under water. The drainage is poor and flows eastward into Cedar Creek. The clay is covered by an overburden which in the unstripped portion amounts to 40 feet and consists of 30 feet of variegated Tuscaloosa clayey sands and 10 feet of Pleistocene gravel. The kaolin is a very white, clean, fine-textured clay, which is reported to become reddish at the base. The mine was opened in 1916, and operations were suspended in 1932. In 1924 a tornado did considerable damage to the plant equipment. The bulk of the output was supplied to the paper trade, but some of it has also entered the rubber and pottery industries. The deposit is an outcropping lens of clay along the west bank of Cedar Creek. Much of the clay near the surface has been mined out, and an increasing overburden is a serious menace to future operations.

Appearance of sample, all good hard white lumps; grinding, fairly easy; plasticity, fairly good, mealy; extrusion, fairly easy; lamination, none; water of plasticity, 33.8 percent; drying shrinkage, 4.1 percent; dry modulus of rupture, 45 pounds to the square inch; drying behavior, no cracking, slight warping; slaking, split to 3-mesh lumps in 4 minutes; settling, no slaking; ground color, fair white; residue on 200 mesh, 0.38 percent; nature of residue, clay (A), muscovite, hematite (T).

Clay disks: Drying shrinkage, 2.6 percent; drying behavior, no cracking; firing shrinkage, 12.2 percent; firing behavior, cracked.

White-ware disks: Drying shrinkage, 2.6 percent; firing shrinkage at cone 9, 8.6 percent; absorption, 5.2 percent; fired appearance, good white color.

Sample 2.—Killian pit, 3 miles by road and trail east of Killian, which is 12 miles northeast of Columbia, S. C., on the Southern Railway. Here 40 feet of variegated clay crops out high on the northwest bank of a ravine affording excellent drainage. A crescent-shaped pit over 500 feet long and 100 feet wide has been excavated. The clays are gritty, micaceous, variegated, and badly stained red. Good firebricks are reported to have been made from these clays; the kilns are on the east side of the Southern Railway tracks at Killian and are now being dismantled. The pit is reported to have been abandoned 15 years ago. The clay bed is capped by a thick limonite shell which is overlain by two strata of white to buff coarse cross-bedded Tuscaloosa sands, each about 20 feet thick. Immediately below the limonite cap is 2 to 3 feet of grayish-white mealy-textured kaolin, from which the sample for test was taken. It includes locally ocher-, purple-, and magenta-stained clays.

Appearance of sample, fair white lumps, off color on the gray side, numerous small brown stains; grinding, easy; plasticity, fair; extrusion, fairly easy; lamination, some; water of plasticity, 37.3 percent; drying shrinkage, 5.1 percent; dry modulus of rupture, 36 pounds to the square inch; drying behavior, very slight cracking and warping; slaking, completely disintegrated in 1 minute 10 seconds; settling, milky suspension settled in 19 minutes, leaving slightly cloudy liquid, clear after 25 minutes; ground color, poor white, buff cast; residue on 200 mesh, 5.77 percent; nature of residue, quartz (A), muscovite.

Clay disks: Drying shrinkage, 4.2 percent; drying behavior, good, slight warping; firing shrinkage, 8.8 percent; firing behavior, no cracking, slight warping.

White-ware disks: Drying shrinkage, 3.8 percent; firing shrinkage at cone 9, 8.6 percent; absorption, 2.4 percent; fired appearance, poor white body, yellow cast, cracked in firing.

Sample 3.—Lexington Clay Mines, Inc., Edmund, S. C., with offices in Columbia, S. C. The plant and mine are on the northwest bank of Hunt Branch of Second Creek, which drains into Congaree Creek and is approximately 2 miles southeast of Edmond, on the Southern Railway. The clay bed is more than 100 feet lower than the railroad tracks at the station (Elev. 461 feet). The overburden consists of coarse cross-bedded micaceous sands, containing prominent brown iron seams and occasional black organic bands. The lower portion of the overburden above the clay is unquestionably Tuscaloosa and may constitute the entire section, as no Barnwell deposits were recognized during a cursory examination. The position of the clay bed about midway along the slope of the ravine provides an excellent opportunity for drainage, but the inclination of the slope is such that the cost of removal of overburden will mount rapidly and soon prevent mining operations. Another unfortunate factor is that the kaolin of commercial grade is overlain by a slightly gritty and discolored clay. If this discolored clay, which is usually about 7 feet thick, can be utilized, it will permit a more extensive mining of the clay bed. The cost of removing unusable clay usually exceeds many times that of removing unconsolidated sandy overburden. The clay bed is reported to have a thickness of 25 feet. Mining operations have so far been confined to and extend along 500 to 600 feet of outcrop. Very little overburden has so far been removed. Sample 3 came from a point 300 feet southwest of the plant and 12 feet below the top of the clay bed. The kaolin is creamy to pale buff when wet but bleaches to a slightly grayish white. It is fine-textured and breaks with a broad, smooth conchoidal fracture. It contains mica and quartz sparingly. Such iron stains as occur are easily trimmed out.

Appearance of sample, good white lumps, somewhat hard; grinding, easy; plasticity, fair, slightly mealy; extrusion, fairly easy; lamination, slight; water of plasticity, 33.6 percent; drying shrinkage, 3.7 percent; dry modulus of rupture, 41 pounds to the square inch; drying behavior, no cracking, some warping; slaking, cracked to 3-mesh lumps in 2 minutes; settling, no slaking; ground color, poor white; residue on 200 mesh, 0.39 percent; nature of residue, clay (A), muscovite (A), hematite (T).

Clay disks: Drying shrinkage, 2.8 percent; drying behavior, slight cracking; firing shrinkage, 11.2 percent; firing behavior, cracked.

White-ware disks: Drying shrinkage, 2.6 percent; firing shrinkage at cone 9, 9.2 percent; absorption, 5.2 percent; fired appearance, good white color.

Sample 4.—Lexington Clay Mines, Inc., Edmund, S. C. This sample came from the same locality as sample 3, but from the banded and red to magenta zone 5 feet below the top of the clay bed. The bands are ¼ to 1 inch wide, horizontal, and apparently due to a rhythmical secondary accumulation of iron in the clay.

Appearance of sample, lumps badly stained red; grinding, fairly easy; plasticity, good; extrusion, easy; lamination, some; water of plasticity, 37.8 percent; drying shrinkage, 4.8 percent; dry modulus of rupture, 39 pounds to the square inch; drying behavior, slight warping, no cracking; slaking, 1¾ minutes to fine grains; settling, milky suspension became cloudy after 1½ minutes and was clear after 1¼ hours; ground color, pink; residue on 200 mesh, 2.17 percent; nature of residue, quartz (A), muscovite (A), hematite, limonite (T).

Clay disks: Drying shrinkage, 4.8 percent; drying behavior, badly cracked; firing shrinkage, 12.4 percent; firing behavior, badly cracked.

White-ware disks: Drying shrinkage, 3.4 percent; firing shrinkage at cone 9, 9.2 percent; absorption, 4.3 percent; fired appearance, extremely poor, speckled by iron.

Sample 5.—Edisto Kaolin Co.'s mine is high on the west bank of the North Fork of the Edisto River and 3 miles east of the Monetta-Wagener road (route 39), Aiken County. (See fig. 4.) This mine at one time supplied a large tonnage of clay, but the abandonment of the Leesville-Perry branch of the Southern Railway seriously handicapped transportation facilities by leaving the mine 15 miles distant from a railroad. The mine has not been in operation for several years. Another difficulty confronting future mining is the rapidly mounting thickness of overburden. The clay bed is overlain by 30 feet of Tuscaloosa cross-bedded sands. Above the Tuscaloosa is a progressively increasing thickness of Barnwell sands, the thickness depending upon the distance from the original outcrop slope. The clay bed is 20 to 25 feet thick. (See tests 50 to 54.) The upper 10 feet is of economic value but contains some grit and locally carries hard inclusions of limonite and limonite stains which must be removed by trimming and selection. A pocket of micaceous clay is enclosed in the exposed clay body. This sample came from the upper 2 feet of the clay face in the northeast corner of the mine. The chunks of kaolin were given such trimming as they would normally receive in mining practice.

Appearance of sample, all good white and somewhat hard lumps; grinding, fairly easy; plasticity, very good; extrusion, easy; lamination, very slight; water of plasticity, 44.6 percent; drying shrinkage, 2.79 percent; dry modulus of rupture, 98 pounds to the square inch; drying behavior, good, slight warping and no cracking; slaking, 1⅝ minutes to fine grains; settling, milky suspension became cloudy after 2 minutes and was clear after 25 minutes; ground color, fairly good; residue on 200 mesh, 0.12 percent; nature of residue, clay (A), quartz, hematite (T).

Clay disks: Drying shrinkage, 5.0 percent; drying behavior, cracking; firing shrinkage, 13.4 percent; firing behavior, slight cracking.

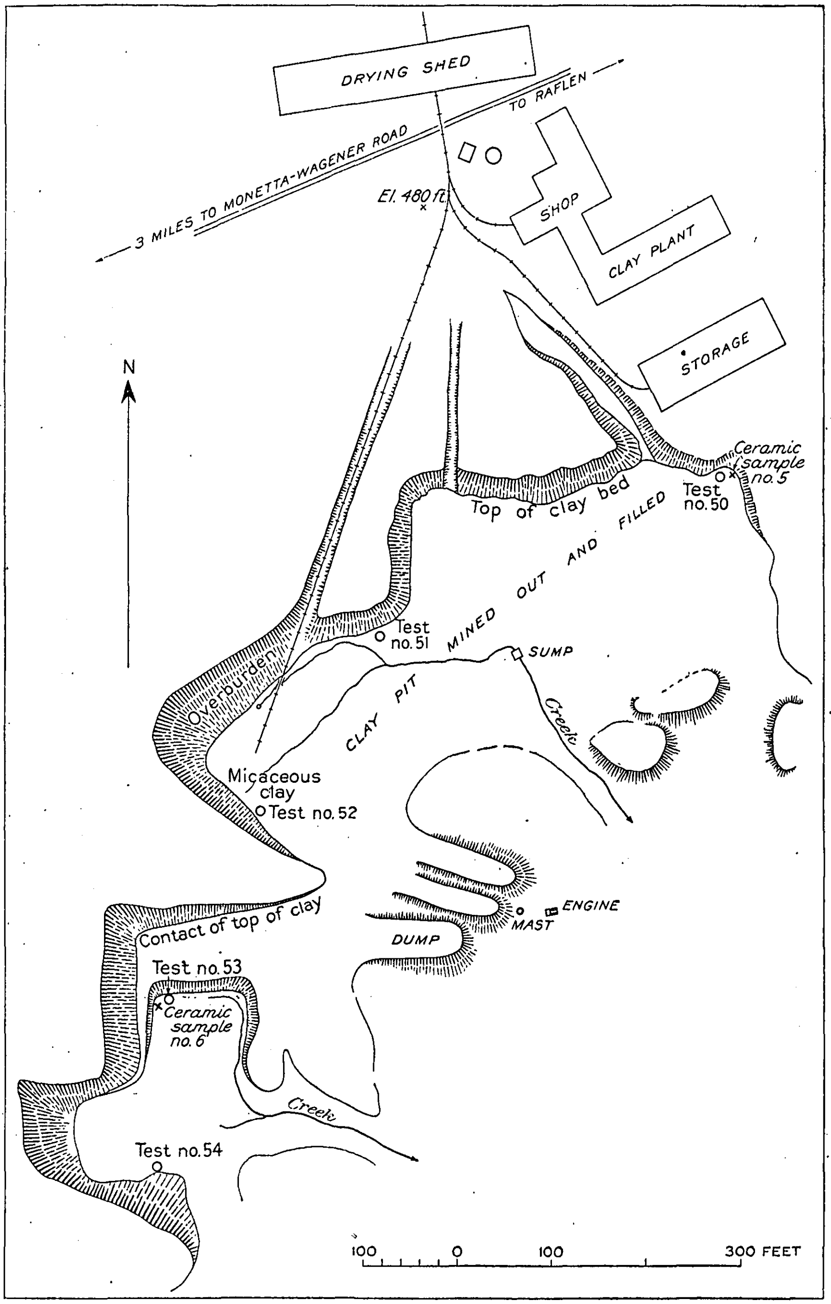


FIGURE 4.—Sketch map of the Edisto Kaolin Co.'s mine, showing location of tests 50–54 and ceramic samples 5 and 6.

White-ware disks: Drying shrinkage, 4.4 percent; firing shrinkage at cone 9, 9.6 percent; absorption, 4.7 percent; fired appearance, good white color.

Sample 6.—Edisto Kaolin Co., Aiken County. (See fig. 4.) Sample taken from the southwestern face of the mine, in a later excavation not completely mined out, 3 feet below the top of the clay. Surfaces trimmed to remove the more obvious limonite inclusions.

Appearance of sample, all good white, somewhat hard, lumps; grinding, easy; plasticity, good, but sticky; extrusion, easy; lamination, slight; water of plasticity, 46.3 percent; drying shrinkage, 3.2 percent; dry modulus of rupture, 77 pounds to the square inch; drying behavior, good, with no cracking and slight warping; slaking, 2⅓ minutes to fine grains; settling, milky suspension became cloudy after 2 minutes and was clear after 25 minutes; ground color, good white, grayish cast; residue on 200 mesh, 0.09 percent; nature of residue, clay (A), quartz, hematite (S).

Clay disks: Drying shrinkage, 5.0 percent; drying behavior, slight cracking; firing shrinkage, 13.2 percent; firing behavior, slight cracking.

White-ware disks: Drying shrinkage, 2.8 percent; firing shrinkage at cone 9, 8.2 percent; absorption, 4.9 percent; fired appearance, very good white body.

Sample 7.—Reddy test pit. The clay bed exposed in the Edisto mine continues southwestward, crossing beneath the Monetta-Wagener highway where it has been lately uncovered on the Reddy property, about half a mile southwest of the Reddy farm house. Tests pits were dug in the spring of 1935, exposing a thick body of clay which in physical appearance presented characteristics very similar to the clays of the Edisto mine. The sample was selected from a point 5 feet below the top of the clay bed, where the best grade of clay so far exposed was found. The upper part shows staining. Although the deeper clays bleach to a beautiful white, they revert to a pale buff when moistened. As the clay accessible for sampling lay near the eroded outcrop, the sample may not be a fair representative of the clay body deeper beneath the overburden, especially with respect to color.

Appearance of sample, fair white lumps; no stains but off color on the buff side; grinding, very easy; plasticity, fairly good; extrusion, easy; lamination, some; water of plasticity, 41.2 percent; drying shrinkage, 4.3 percent; dry modulus of rupture, 16 pounds to the square inch; drying behavior, bad lateral cracking and bad warping; slaking, completely disintegrated in 1 minute; settling, milky suspension settled in 15 minutes, leaving slightly cloudy liquid; clear after 30 minutes; ground color, poor white, buff cast; residue on 200 mesh, 0.25 percent; nature of residue, muscovite (A), quartz.

Clay disks: Drying shrinkage, 3.0 percent; drying behavior, good, no cracking; firing shrinkage, 11.0 percent; firing behavior, slightly cracked.

White-ware disks: Drying shrinkage, 2.4 percent; firing shrinkage, at cone 9, 10.0 percent; absorption, 2.4 percent; fired appearance, fair white body, cracked in firing.

Sample 8.—Southeastern Clay Co., Aiken County. Plant at Croft, on the east bank of Shaw Creek, served by the branch line of the Southern Railway from Aiken to Trenton. The plant is not situated by a clay mine but is supplied with kaolin trucked in from pits within a radius of 5 miles. The Piper pit, from which this sample of kaolin was obtained, is at the head of Little Branch, a tributary of the South Fork of the Edisto River, and an eighth of a mile east of the Columbia Highway (U. S. 1). (See fig. 5.) The clay bed is 12 feet thick, variably gritty to gritless, stained buff to pinkish purple, and breaks into bladed chunks with a crumbly surface. It is overlain by 20 feet of reddish to pale-buff Barnwell sands. The sample was taken from the center of the south wall of clay in the pit.

Appearance of sample, white lumps with some light-brown stains; grinding, easy; plasticity, fair but mealy; extrusion, fairly easy; lamination, none; water of plasticity, 39.5 percent; drying shrinkage, 3.5 percent; dry modulus of rupture, 54 pounds to the square inch; drying behavior, no cracking and very slight warping; slaking, none; settling, no slaking; ground color, poor white; residue on 200 mesh, 0.95 percent; nature of residue, clay (A), quartz, hematite (T).

Clay disks: Drying shrinkage, 3.2 percent; drying behavior, cracked; firing shrinkage, 18.6 percent; firing behavior, cracked.

White ware disks: Drying shrinkage, 4.4 percent; firing shrinkage at cone 9, 8.8 percent; absorption, 4.0 percent; fired appearance, poor white color.

Sample 9.—Southeastern Clay Co., Gunter pit, on property of B. Gunter, three-quarters of a mile east of the Columbia Highway (U. S. 1) on the east side

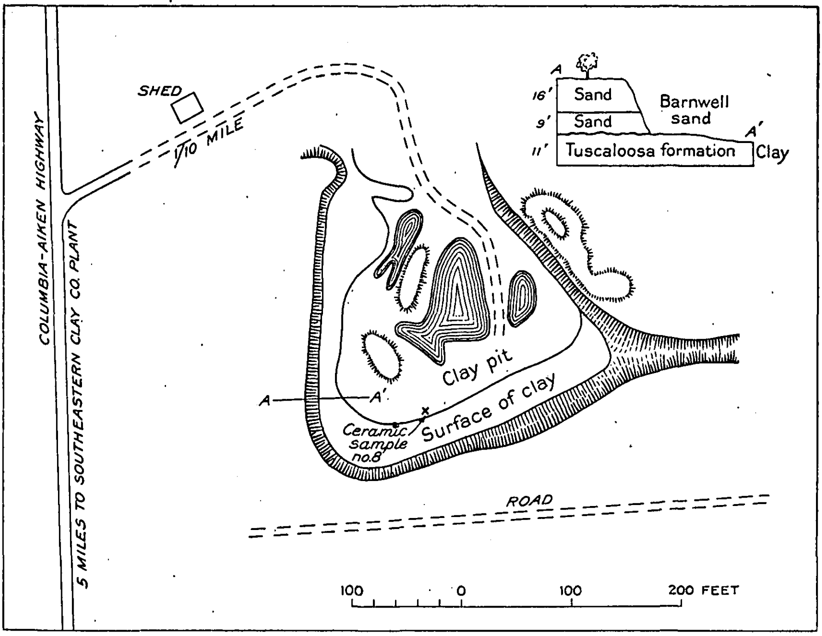


FIGURE 5.—Sketch map of the Southeastern Clay Co.'s Piper pit, Aiken County, S. C., showing location of ceramic sample 8.

of the upper reaches of Bradley Mill Branch, about 6 miles north of Aiken. (See fig. 6.) The pit was first opened in March 1934 and at the time the clay bed was sampled was but 45 feet wide. The maximum exposed thickness of the clay is 15 feet. The clay is very free of grit and is stained buff to purplish with occasional nodules of iron oxide. It has a bladed structure, breaks with a rough surface, and has a greenish cast when moist but bleaches out white. The clay bed is variable in thickness and is overlain by Barnwell sand 4 to 12 feet thick.

Appearance of sample, good white lumps with slight yellow stains; grinding, easy; plasticity, fair; extrusion, easy; lamination, none; water of plasticity, 44.3 percent; drying shrinkage, 3.5 percent; dry modulus of rupture, 88 pounds to the square inch; drying behavior, slight cracking but no warping; slaking, to 8-mesh lumps in 2¼ minutes; settling, became slightly cloudy and cleared in 10 minutes; ground color, poor white; residue on 200 mesh, 0.23 percent; nature of residue, clay (A), quartz, iron oxide.

Clay disks: Drying shrinkage, 4.0 percent; drying behavior, cracked; firing shrinkage, 16.4 percent; firing behavior, fair.

White-ware disks: Drying shrinkage, 4.0 percent; firing shrinkage at cone 9, 9.0 percent; absorption, 4.9 percent; fired appearance, poor white color.

Sample 10.—Southeastern Clay Co., Morris pit, on the west bank of the upper end of Bridge Creek, 1 mile west of the Edgefield road and 5 miles north of Aiken. The clay outcrop occurs about midway on the slope of the valley. A pit 190 feet long and 55 feet wide has been opened up. The clay bed is 5½ feet thick and is covered on the high side by 16 feet of Barnwell sand. (See test 55, p. 61.) The clay shows a bladed structure, is variably stained buff to pinkish, and contains some grit and mica. When dry the clay bleaches to a very clear white. Practically all of the clay bed is usable, with the exception of variable coarse grit inclusions at the top and 6 inches of clay at the base, which is discolored and micaceous.

Appearance of sample, good white lumps with slight brown stains; grinding,

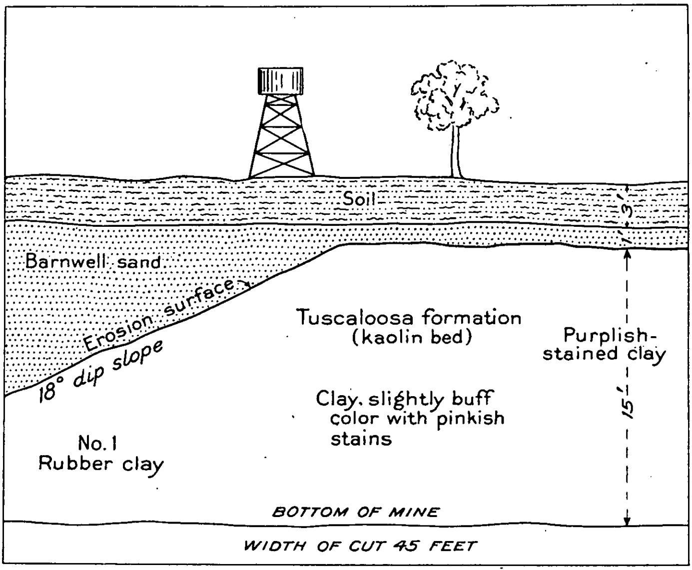


FIGURE 6.—Gunter pit, Southeastern Clay Co., near Aiken, S. C., showing unconformity of Barnwell sand on clay of Tuscaloosa age.

easy; plasticity, fairly good, mealy; extrusion, fairly easy; lamination, very little; water of plasticity, 44.1 percent; drying shrinkage, 5.1 percent; dry modulus of rupture, 68 pounds to the square inch; dry behavior, very good, no cracking or warping; slaking, 3½ minutes to fine grains; settling, milky for 2 minutes, cloudy for 30 minutes; ground color, poor white; residue on 200 mesh, 0.42 percent; nature of residue, clay (A), quartz (A), muscovite (A), iron oxide (T).

Clay disks: Drying shrinkage, 4.4 percent; drying behavior, cracked; firing shrinkage, 11.8 percent; firing behavior, cracked.

White-ware disks: Drying shrinkage, 6.4 percent; firing shrinkage at cone 9, 8.8 percent; absorption, 5.1 percent; fired appearance, fair white color.

Sample 11.—The China Spring bed of clay occurs in a stream valley tributary to Bridge Creek in which is located old China Spring Church, 3 miles north of Aiken and three-quarters of a mile west of the Edgefield road. (See fig. 7.) The clay crops out on both sides of the ravine, but extensive mining in the past has been confined to the north bank. The pit is now abandoned but was recently worked by the Southeastern Clay Co. The clay possesses many good qualities but is slightly too gritty for direct commercial use. The north wall of the pit supports an overburden of 40 feet of sand. The upper 7 feet of clay is gritty, whitish to buff, and iron-stained, beneath which is 1 foot of purplish gritty micaceous clay. This is underlain by a very white fine-textured kaolin, 6 feet of which is exposed at the bottom of the pit. The sample represents this bottom bed of white clay.

Appearance of sample, good white lumps, very little stain; grinding, easy; plasticity, fair but mealy; extrusion, difficult; lamination, very little; water of plasticity, 33.5 percent; drying shrinkage, 3.8 percent; dry modulus of rupture, 33 pounds to the square inch; drying behavior, slight warping, no cracking; slaking, none except that corners ruptured; settling, no slaking; ground color, poor white; residue on 200 mesh, 1.89 percent; nature of residue, clay (A), quartz (A), muscovite (A).

Clay disks: Drying shrinkage, 2.4 percent; drying behavior, slight cracking; firing shrinkage, 12.6 percent; firing behavior, very badly cracked.

White-ware disks: Drying shrinkage, 2.4 percent; firing shrinkage, at cone 9, 9.4 percent; absorption, 4.6 percent; fired appearance, extremely good white color.

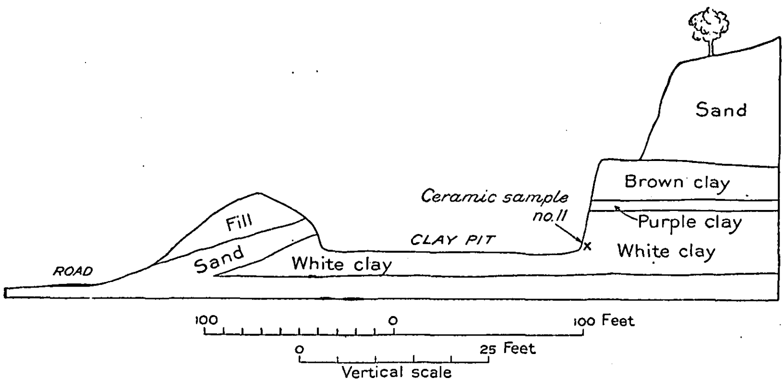


FIGURE 7.—Sketch map and section of China Spring clay pit, Southeastern Clay Co., showing location of ceramic sample 11.

Sample 12.—Toole pit. A very colorful outcrop of clay occurs across the Aiken-Vaucluse highway near a junction point a quarter of a mile east of Bridge Creek. The clay outcrop is traceable northward for some distance along the slope and has been worked at various times for many years past, original excavations dating back to Civil War days. Recently a new pit was opened up by the Southeastern Clay Co. between the two connecting roads. The clay lens is variable in thickness but may amount to 25 feet or more. It is also variably gritty and micaceous, and, unfortunately, as at China Spring, the better grade of clay is overlain by discolored and gritty clay. The upper portion is predominately buff but includes clay of very striking pinkish and rose red to purplish hues. The sample was selected from a seam of white clay in the new pit.

Appearance of sample, all good white lumps; grinding, fairly easy; plasticity, fair, slightly mealy; extrusion, fairly easy; lamination, slight; water of plasticity, 41.2 percent; drying shrinkage, 4.1 percent; dry modulus of rupture, 52 pounds to the square inch; drying behavior, slight warping, cracked; slaking, split to 3-mesh lumps in 5 minutes; settling, practically no slaking, faintly cloudy for

5 minutes; ground color, poor white; residue on 200 mesh, 1.17 percent; nature of residue, muscovite (A), clay, hematite (T).

Clay disks: Drying shrinkage, 2.2 percent; drying behavior, slight cracking; firing shrinkage, 12.0 percent; firing behavior, cracked.

White-ware disks: Drying shrinkage, 2.8 percent; firing shrinkage at cone 9, 8.6 percent; absorption, 4.8 percent; fired appearance, good white color.

Sample 13.—Graniteville mine, Huber Corporation. This mine is 2 miles in a westerly direction from either Graniteville or Warrenville, on the divide between Horse Creek and Little Horse Creek. (See fig. 8.) A plant for drying, grinding, air cleaning, and bagging the clay has been constructed at the mine site, which is to the north across the road from the old Sterling Clay Co. mine, now abandoned. This property has been extensively mined, and recently additional stripping has exposed to view 40,000 square feet of clay surface. The clay ranges from a knife edge to 35 feet or more in thickness. It also varies in grit content, but the color remains fairly uniform and is a whitish to pale buff variably stained buff and pinkish. The clay is tough and crumbly with a bladed structure and along with the Piper clay (see p. 68) represents the finest rubber clays to be found anywhere in the eastern Coastal Plain. Much of the variation in thickness of the bed is a result of post-Tuscaloosa erosion. From 20 to 35 feet of Barnwell sand overlies the clay bed in the new pit. The sample was taken from the center of the clay face being mined in the western part of the new pit.

Appearance of sample, good white lumps with considerable brown staining; grinding, fairly easy; plasticity, very good; extrusion, easy; lamination, slight; water of plasticity, 41.6 percent; drying shrinkage, 4.3 percent; dry modulus of rupture, 61 pounds to the square inch; drying behavior, cracking with slight warping; slaking, 4½ minutes to coarse grains; settling, formed slightly cloudy suspension which cleared in 12 minutes; ground color, poor white; residue on 200 mesh, 0.78 percent; nature of residue, clay (A), quartz (A), hematite (T).

Clay disks: Drying shrinkage, 5.0 percent; drying behavior, no cracking; firing shrinkage, 18.2 percent; firing behavior, slight cracking.

White-ware disks: Drying shrinkage, 4.0 percent; firing shrinkage, at cone 9, 9.4 percent; absorption, 4.3 percent; fired appearance, poor white color.

Sample 14.—Richardson pit. This is a new pit opened up in the spring of 1935 by the Huber Corporation at the head of Town Creek, half a mile south of the Pine Log road. The clay is transported by truck to either the Langley or the Graniteville plant of the Huber Corporation for processing. The clay crops out at the surface and was truncated during valley erosion, and as a result the initial opening of the pit required the removal of only an insignificant amount of surface covering. There is 12 feet of usable clay exposed. It has a grayish to buff cast and is variably stained, a tough crumbly clay that requires shooting to prepare it for loading. It is quite free of grit and bleaches white with a slight grayish cast.

Appearance of sample, fair white lumps, grayish cast, no segregated stains; grinding, very easy; plasticity, fair, very mealy; extrusion, fairly easy; lamination, slight; water of plasticity, 37.5 percent; drying shrinkage, 4.1 percent; dry modulus of rupture, 25 pounds to the square inch; drying behavior, very slight warping and cracking; slaking, slaked to 8 mesh lumps in 5 minutes 30 seconds; settling, milky suspension settled in 12 minutes, leaving slightly cloudy liquid; clear after 1 hour 30 minutes; ground color, fair white, buff cast; residue on 200 mesh, 0.1 percent; nature of residue, clay (A), quartz, muscovite, hematite.

Clay disks: drying shrinkage, 3.0 percent; drying behavior, bad warping, slight cracking; firing shrinkage, 17.0 percent; firing behavior, cracked, badly warped.

White-ware disks: Drying shrinkage, 3.6 percent; firing shrinkage at cone 9, 9.0 percent; absorption, 2.0 percent; firing appearance, poor white body, yellow cast, badly cracked.

Sample 15.—Clara Harrigal pit. This pit was uncovered by the Huber Cor-

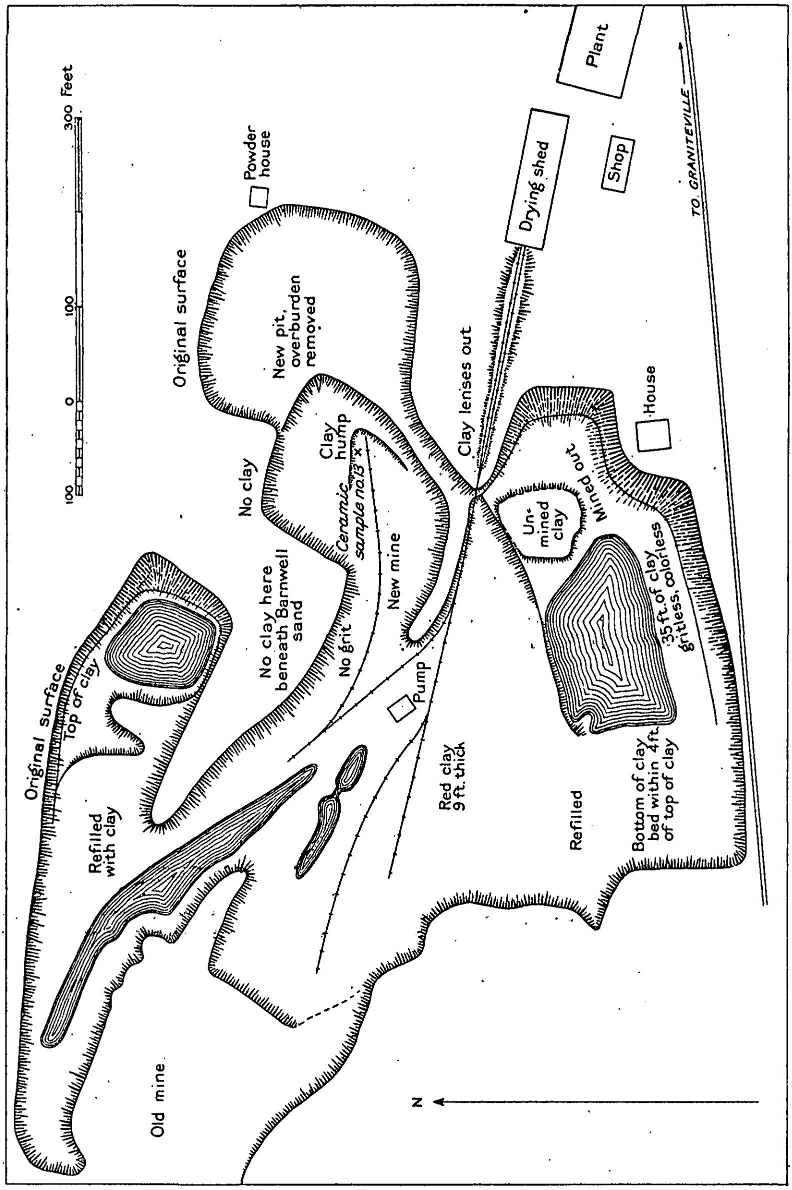


FIGURE 8.—Sketch map of Graniteville mine of Huber Corporation, Aiken County, S. C., showing location of ceramic sample 13.

poration in the spring of 1935. It is near the head of Town Creek, on the east bank less than a mile south of the Richardson pit. It is a continuation southward of the clay bed exposed in the Richardson pit. Test 46 penetrated this same bed south of the Harrigal pit. This clay also crops out, and at present a 10-foot face is exposed, which had been carried back less than 20 feet into the body of clay at the time of sampling. The clay is very similar to the Richardson material. It is pale buff where moist but dries to a slightly grayish white and most of the discoloration bleaches out. Like other rubber clays, it makes up into a far better finished product than would appear probable when the crude product in the mine is seen. It is a tough bladed clay breaking with a hackly surface. Under the influence of a drenching rain a freshly mined face of clay crumbles into a coarse talus, a habit that seems to be characteristic of clay suitable for rubber.

Appearance of sample, fair white lumps; buff cast, brown stains; grinding, very easy; plasticity, fair, mealy; extrusion, fair; lamination, slight; water of plasticity, 41.0 percent; drying shrinkage, 5.2 percent; dry modulus of rupture, 21 pounds to the square inch; drying behavior, slight lateral cracking, very slight warping; slaking, completely disintegrated in 45 seconds; settling, milky suspension settled in 11 minutes, leaving slightly cloudy liquid; clear after 35 minutes; ground color, fair white, buff cast; residue on 200 mesh, 0.05 percent; nature of residue, clay (A), quartz (A), muscovite, hematite.

Clay disks: Drying shrinkage, 5.2 percent; drying behavior, slight warping and cracking; firing shrinkage, 17.0 percent; firing behavior, cracked, warped.

White-ware disks: Drying shrinkage, 2.8 percent; firing shrinkage at cone 9, 8.2 percent; absorption, 2.2 percent; fired appearance, poor white body, yellow cast, badly cracked.

Sample 16.—Harrigal pit, Town Creek. Within the sands overlying the Harrigal clay pit are balls of clay of various sizes and kinds. The occurrence of clay balls is not uncommon in the upper part of the Tuscaloosa and occasionally in the Barnwell. These clay balls originated as a result of erosion of clay beds previously deposited and are intraformational conglomerates. As a result the texture and quality of the clay in each ball varies in accordance with the type of clay bed from which it was derived. A gritty clay ball may be lodged against one that is highly micaceous, which in turn may be in contact with one of the cleanest and finest of clays. The outstanding feature of these clay balls is their whiteness, which is probably due to the leaching effect of acid ground waters. The outer surface of many of the balls is impregnated with sand grains picked up in transit, and the very soft balls have had grit and brown clay inclusions rolled into them. The following ceramic test is that of a 15-inch clay cobble as nearly representative of the balls as could be selected. It is possible to find all variations of types of clay. Color seems to be the only feature that does not vary. Some clay balls were found of a whiteness, fineness of texture, and plasticity unlike those of any of the clay beds examined.

Appearance of sample, very good white lumps, but with some brown stains and some fine grit; grinding, very easy; plasticity, poor; extrusion, fair; lamination, bad; water of plasticity, 39.8 percent; drying shrinkage, 4.6 percent; dry modulus of rupture, 10 pounds to the square inch; drying behavior, no cracking, slight warping; slaking, completely disintegrated in 40 seconds; settling, milky suspension settled in 18 minutes, leaving clear liquid; ground color, very good white; residue on 200 mesh, 1.73 percent; nature of residue, muscovite (A), quartz, clay.

Clay disks: Drying shrinkage, 2.6 percent; drying behavior, good; firing shrinkage, 7.4 percent; firing behavior, very slightly cracked.

White-ware disks: Drying shrinkage, 2.8 percent; firing shrinkage at cone 9 10.0 percent; absorption, 3.2 percent; fired appearance, fair white body, slightly cracked in firing.

Sample 17.—Immaculate Kaolin Co.'s mine, 2½ miles southeast of Langley and immediately southeast of the Pine Log road. The mine consists of two pits, arranged L shape, one extending northward, the other eastward. Recently additional stripping has been done along the northwest wall of the east pit. A test hole (no. 56), was put down through the bed of clay which began at the Barnwell-Tuscaloosa contact. The overburden at this point is 35 feet thick. This clay sample came from the top 2 feet of clay.

Appearance of sample, all good white lumps with some slight brown stains; grinding, easy; plasticity, good; extrusion, easy; lamination, slight; water of plasticity, 40.8 percent; drying shrinkage, 3.9 percent; dry modulus of rupture, 40 pounds to the square inch; drying behavior, bars cracked; slaking, 1¾ minutes to medium grain size; settling, cloudy suspension cleared in about 1 hour; ground color, fair white; residue on 200 mesh, 0.14 percent; nature of residue, clay (A), quartz.

Clay disks: Drying shrinkage, 3.6 percent; drying behavior, cracked badly; firing shrinkage, 14.6 percent; firing behavior, no additional cracks.

White-ware disks: Drying shrinkage, 3.8 percent; firing shrinkage at cone 9, 9.2 percent; absorption, 5.2 percent; fired appearance, poor white color.

Sample 18.—Immaculate Kaolin Co.'s mine. This sample was obtained from the drying sheds of the plant and represents the extremely fine-textured and plastic clay found in the lower section of the clay bed.

Appearance of sample, lumps showed considerable pink stains; grinding, easy; plasticity, slightly overplastic; extrusion, poor; lamination, some; water of plasticity, 42.8 percent; drying shrinkage, 5.9 percent; dry modulus of rupture, 89 pounds to the square inch; drying behavior, developed evidence of die ragging, but no cracks; slaking, 2 minutes to fairly dry grain size; settling, milky suspension formed and became cloudy after 1½ minutes, became clear in 26 minutes; ground color, light gray pink; residue on 200 mesh, 0.06 percent; nature of residue, clay stained with hematite (A).

Clay disks: Drying shrinkage, 4.0 percent; drying behavior, cracked; firing shrinkage, 13.4 percent; firing behavior, no additional cracks.

White-ware disks: Drying shrinkage, 3.6 percent; firing shrinkage at cone 9, 9.4 percent; absorption, 3.5 percent; fired appearance, very poor white, yellow tinge.

Sample 19.—Immaculate Kaolin Co. Sample taken from test hole 56, at 20 to 23 feet below the top of the kaolin bed. It is a very fine-textured clay colored black by organic material. This clay is an ebony black when wet but becomes brown to grayish brown when dry. Its very high tensile strength is worthy of note.

Appearance of sample, grayish-brown lumps with white clay nodules; grinding, fairly easy; plasticity, very good; extrusion, very easy; lamination, slight; water of plasticity, 44.5 percent; drying shrinkage, 5.6 percent; dry modulus of rupture, 266 pounds to the square inch; drying behavior, slight warping, no cracking; slaking, only white nodules slaked; settling, no slaking; ground color, grayish brown; residue on 200 mesh, 0.93 percent; nature of residue, quartz (A), organic matter (A), magnetite.

Clay disks: Drying shrinkage, 5.2 percent; drying behavior, no cracking; firing shrinkage, 13.4 percent; firing behavior, cracked.

White-ware disks: Drying shrinkage, 3.6 percent; firing shrinkage at cone 9, 9.2 percent; absorption, 4.1 percent; fired appearance, poor white color.

Sample 20.—The North American-Continental mine is 2 miles southeast of Langley, S. C., on the northwest side of the Pine Log road, across from the Immaculate Kaolin Co.'s mine. The sample was taken from the middle portion of a 20-foot wall of kaolin on the southeast face of the mine.

Appearance of sample, all good hard white lumps; grinding, easy; plasticity, fair, slightly mealy; extrusion, fair; lamination, slight; water of plasticity, 46.9 percent; drying shrinkage, 4.8 percent; dry modulus of rupture, 47 pounds to the square inch; drying behavior, cracked, slight warping; slaking, split to 8-mesh lumps in 1 minute, some slaking; settling, very cloudy for half a minute, clear after half an hour; ground color, fair white; residue on 200 mesh, 0.16 percent; nature of residue, clay (A), muscovite (T), hematite (T).

Clay disks: Drying shrinkage, 3.4 percent; drying behavior, slightly cracked; firing shrinkage, 14.4 percent; firing behavior, cracked.

White-ware disks: Drying shrinkage, 3.8 percent; firing shrinkage at cone 9, 9.4 percent; absorption, 4.6 percent; fired appearance, fair white color.

Sample 21.—J. R. Parker, Chicora pit. This is a relatively new pit half a mile west of the Immaculate Kaolin Co.'s plant, near the head of a ravine that drains into Horse Creek at Langley. The bed of clay attains a thickness of 40 feet and is overlain by 30 feet or more of Barnwell sand where mining has been carried deepest into the bank. The lower 10 feet of clay, which was not exposed in the pit, is locally highly colored red, purple, and black. The upper 30 feet, though superficially appearing uniform, is divisible into three 10-foot sections in accordance with quality. Clay from the top 10-foot section will not diffuse in rubber and is therefore useless for this purpose. The second 10 feet is a good grade of rubber clay, and the third 10-foot section is also reported to have value for rubber but is not so satisfactory as the second. Representative samples have been taken of the three sections; sample 21 came from the top 10 feet.

Appearance of sample, all good white lumps; grinding, easy; plasticity, good; extrusion, very easy; lamination, some; water of plasticity, 35.2 percent; drying shrinkage, 3.3 percent; dry modulus of rupture, 56 pounds to the square inch; drying behavior, cracked; slaking, 1¼ minutes to medium grain size; settling, slightly cloudy suspension cleared after 4 minutes; ground color, fair white; residue on 200 mesh, 0.76 percent; nature of residue, clay (A), quartz (A), hematite (T).

Clay disks: Drying shrinkage, 2.8 percent; drying behavior, cracked badly; firing shrinkage, 17.8 percent; firing behavior, cracked badly.

White-ware disks: Drying shrinkage, 3.8 percent; firing shrinkage at cone 9, 9.6 percent; absorption, 4.2 percent; fired appearance, poor white color, yellow tinge.

Sample 22.—This sample represents the second 10-foot section of the Chicora clay pit and came from a position 15 feet below the top of the clay bed.

Appearance of sample, all good white lumps; grinding, easy; plasticity, fair; extrusion, difficult; lamination, some; water of plasticity, 36.4 percent; drying shrinkage, 3.4 percent; dry modulus of rupture, 63 pounds to the square inch; drying behavior, cracked with slight warping; slaking, 6 minutes to medium grain size; settling, very cloudy suspension for 1 hour; ground color, good white; residue on 200 mesh, 0.09 percent; nature of residue, clay (A), muscovite, hematite (T).

Clay disks: Drying shrinkage, 3.0 percent; drying behavior, cracked; firing shrinkage, 11.2 percent; firing behavior, cracked.

White-ware disks: Drying shrinkage, 3.8 percent; firing shrinkage at cone 9, 8.2 percent; absorption, 5.4 percent; fired appearance, good white color.

Sample 23.—Sample selected from a point 25 feet below the top of the clay bed near the bottom of the Chicora pit and representative of the third 10-foot section of clay.

Appearance of sample, good white lumps; grinding, easy; plasticity, good; extrusion, fairly easy; lamination, some; water of plasticity, 38.4 percent; drying shrinkage, 3.6 percent; dry modulus of rupture, 44 pounds to the square inch; drying behavior, very slight warping, some cracking; slaking, 5½ minutes to medium grain size; settling, very cloudy suspension for 1 hour; ground color, good white; residue on 200 mesh, 0.15 percent; nature of residue, clay (A), quartz, hematite (T), muscovite, (T).

Clay disks: Drying shrinkage, 4.0 percent; drying behavior, cracked; firing shrinkage, 14.2 percent; firing behavior, cracked.

White-ware disks: Drying shrinkage, 3.4 percent; firing shrinkage at cone 9, 9.2 percent; absorption, 4.7 percent; fired appearance, fair white color.

Sample 24.—Harmon pit, North American Clay Co. This pit lies due south of the Chicora pit and on the south side of the same ravine. The clay being mined is also from the same bed, and at present a maximum of 45 feet of Barnwell sand overlies the clay bed. This sample was taken from the southwestern part of the pit, where the clay bed has thinned to less than 15 feet. The clay contains some iron nodules and buff stains, which trimming easily removes.

Appearance of sample, good white lumps, very small amount of pink stains; grinding, easy; plasticity, good but slightly sticky; extrusion, fairly easy; lamination, some; water of plasticity, 41.7 percent; drying shrinkage, 4.6 percent; dry modulus of rupture, 73 pounds to the square inch; drying behavior, some warping and slight cracking; slaking, 3 minutes to fairly fine grain; settling, very cloudy suspension, clear after 1¼ hours; ground color, fair white; residue on 200 mesh, 0.09 percent; nature of residue, clay (A), quartz (T), muscovite (T), hematite (T).

Clay disks: Drying shrinkage, 2.8 percent; drying behavior, cracked; firing shrinkage, 13.0 percent; firing behavior, no additional cracks.

White-ware disks: Drying shrinkage, 3.0 percent; firing shrinkage at cone 9, 8.8 percent; absorption, 4.6 percent; fired appearance, fair white color.

Sample 25.—Old Parker pit, about 2 miles south of Langley, S. C., joined on the west and south by properties operated by the Huber Corporation. The sample was obtained 3 feet below the top of the clay bed at the north end of the old mine. This clay bed holds the same stratigraphic position as the producing beds in the adjacent pits.

Appearance of sample, good white lumps with slight brown staining; grinding, easy; plasticity, poor, short; extrusion, difficult; lamination, bad; water of plasticity, 28.8 percent; drying shrinkage, 3.1 percent; dry modulus of rupture, 25 pounds to the square inch; drying behavior, slightly cracked and some warping; slaking, 2 minutes, mostly to 3-mesh lumps, but some to fine grain; settling, cloudy for 1 hour; ground color, ivory; residue on 200 mesh, 0.13 percent; nature of residue, clay (A), muscovite (A), quartz (T), limonite (T), hematite (T).

Clay disks: Drying shrinkage, 2.0 percent; drying behavior, slight cracking; firing shrinkage, 10.2 percent; firing behavior, no additional cracks.

White-ware disks: Drying shrinkage, 2.4 percent; firing shrinkage at cone 9, 7.8 percent; absorption, 5.2 percent; fired appearance, good white color.

Sample 26.—Alum pit, Huber Corporation, the southernmost pit operated by the Huber Corporation, a third of a mile southeast of the Langley plant. It is a very clean white clay of fine texture and breaks into conchoidal slabs with a slight hackly surface.

Appearance of sample, all good white lumps; grinding, fairly easy; plasticity, good; extrusion, easy; lamination, some; water of plasticity, 35.7 percent; drying shrinkage, 4.9 percent; dry modulus of rupture, 92 pounds to the square inch; drying behavior, slight cracking with some warping; slaking, to about 3 mesh in 2 minutes and 4 mesh in 30 minutes; settling, very little fine material, but formed cloudy suspension which became clear after about 1 hour; ground color, good white; residue on 200 mesh, 0.31 percent; nature of residue, clay (A), magnetite (T), muscovite (T).

Clay disks: Drying shrinkage, 4.4 percent; drying behavior, no cracking; firing shrinkage, 11.6 percent; firing behavior, no cracking.

White-ware disks: Drying shrinkage, 3.4 percent; firing shrinkage at cone 9, 8.4 percent; absorption, 5.3 percent; fired appearance, fairly white body.

Sample 27.—South Carolina Clay Co.'s mine, 2 miles due south of Langley and midway along the clay outcrop that supports the operations of the Huber Corporation and the North American-McNamee mine. This is one of the oldest mines in the district, and practically all of the shallow clay has been removed. Mining is being carried southward with a rising overburden of sands of Tuscaloosa age which now exceeds 45 feet. The sample was taken from the middle of the south wall of the mine, 3 feet below the top of the clay.

Appearance of sample, all good white lumps; grinding, easy; plasticity, fair; extrusion, fairly easy; lamination, bad; water of plasticity, 33.4 percent; drying shrinkage, 4.1 percent; dry modulus of rupture, 59 pounds to the square inch; drying behavior, very slight warping, slight cracking; slaking, 2½ minutes to fine grain; settling, milky suspension cloudy after 1 minute and became clear after 1¼ hours; ground color, good white; residue on 200 mesh, 0.93 percent; nature of residue, nearly all muscovite.

Clay disks: Drying shrinkage, 4.2 percent; drying behavior, cracked; firing shrinkage, 11.2 percent; firing behavior, cracked.

White-ware disks: Drying shrinkage, 3.4 percent; firing shrinkage at cone 9, 8.6 percent; absorption, 4.8 percent; fired appearance, fair white color.

Sample 28.—North American-McNamee mine, probably the oldest large kaolin mine in South Carolina, 1½ miles south of Bath. The mine includes a group of pits, one of which extends for more than two-thirds of a mile along the outcrop and connects with the South Carolina Clay Co.'s pit on the east. This sample was obtained from the south wall of the pit west of the plant, between the spur-line railroad and the road from Bath to the Pine Log road. It is a beautiful clean white clay that breaks off in large conchoidal slabs and is very uniform in quality. An 8-foot bed of clay was exposed and chunks were taken from the middle 4 feet.

Appearance of sample, all good white lumps with no stains; grinding, easy; plasticity, fairly good; extrusion, easy; lamination, some; water of plasticity, 37.7 percent; dry shrinkage, 4.6 percent; dry modulus of rupture, 24 pounds to the square inch; drying behavior, slight lateral cracking and slight warping; slaking, completely disintegrated in 1 minute 30 seconds; settling, milky suspension settled in 13 minutes leaving slightly cloudy liquid, clear after 30 minutes; ground color, fairly good white; residue on 200 mesh, 0.15 percent; nature of residue, quartz (A), muscovite (A), hematite (T).

Clay disks: Drying shrinkage, 3.8 percent; drying behavior, good, no cracking; firing shrinkage, 9.2 percent; firing behavior, cracked, no warping.

White-ware disks: Drying shrinkage, 2.6 percent; firing shrinkage, at cone 9, 9.4 percent; absorption, 2.6 percent; fired appearance, fair white body, cracked in firing.

Samples 29–31.—Deeply altered crystalline rocks overlain by a thin cover of Barnwell sand are exposed in the 90-foot cut of the Georgia-Florida Railroad on the divide between Shaver and Horn Creeks. In the northwest quarter of the Warrenville quadrangle the rocks of the Piedmont are of different types, much contorted, altered, and completely weathered. Three samples (A, B, C, pl. 2) of white residual clays were taken from the east side of the cut mentioned—No. 29 from the north side of the crown of the cut and Nos. 30 and 31 to the south, near the water sump. All specimens appear to have been originally pegmatites, rich in feldspar. No detailed study of these rocks has been made. Their indefinitely outlined exposures cover areas of 10 to 20 square feet. Despite the very general character of the samples the tests provide some indication of the quality of white residual clays in the Piedmont region along the Fall Line.

Sample 29.—Appearance of sample, white lumps containing a very high percentage of coarse mica and quartz; grinding, easy; plasticity, extremely poor;

extrusion, very difficult; lamination, none; water of plasticity, 19.9 percent; drying shrinkage, 2.5 percent; dry modulus of rupture, 14 pounds to the square inch; drying behavior, no warping or cracking; slaking, 1¼ minutes giving fine clay particles and coarse grit; settling, milky suspension for 2½ minutes and cloudy for 28 minutes; ground color, very good white; residue on 200 mesh, 46.2 percent; nature of residue, quartz (A), muscovite (A), both very coarse.

Clay disks: Drying shrinkage, 2.0 percent; drying behavior, no cracking; firing shrinkage, 6.8 percent; firing behavior, slight cracking.

White-ware disks: Drying shrinkage, 2.8 percent; firing shrinkage at cone 9, 9.6 percent; absorption, 4.5 percent; fired appearance, good white color.

Sample 30.—Appearance of sample: white lumps containing finer-grained quartz and mica than sample 29; grinding, easy; plasticity, poor; extrusion, fairly easy; lamination, none; water of plasticity, 28.7 percent; drying shrinkage, 3.4 percent; dry modulus of rupture, 39 pounds to the square inch; drying behavior, no cracking or warping; slaking, half a minute, giving fine clay and coarse grit; settling, milky for 2½ minutes, cloudy for 25 minutes; ground color, very good white; residue on 200 mesh, 42.9 percent; nature of residue, quartz (A), muscovite (A), hematite (T).

Clay disks: Drying shrinkage, 3.2 percent; drying behavior, slightly cracked; firing shrinkage, 8.6 percent; firing behavior, slightly cracked.

White-ware disks: Drying shrinkage, 2.2 percent; firing shrinkage at cone 9, 9.8 percent; absorption, 5.0 percent; fired appearance, good white color.

Sample 31.—Appearance of sample, white lumps of clay containing coarse quartz and some mica; grinding, easy; plasticity, poor; extrusion, fairly easy; lamination, none; water of plasticity, 25.8 percent; drying shrinkage, 3.3 percent; dry modulus of rupture, 33 pounds to the square inch; drying behavior, no cracking, no warping; slaking, 2 minutes, fine clay and coarse grit; settling, very milky for 10 minutes, cloudy for additional 1¼ hours; ground color, very poor white, decided yellow tinge; residue on 200 mesh, 37.6 percent; nature of residue, quartz (A), muscovite, clay, limonite (T).

Clay disks: Drying shrinkage, 2.0 percent; drying behavior, no cracking; firing shrinkage, 11.8 percent; firing behavior, no cracking.

White-ware disks: Drying shrinkage, 2.0 percent; firing shrinkage at cone 9, 11.0 percent; absorption, 2.3 percent; fired appearance, good white color.

SUMMARY

These tests provide only a preliminary picture of the adaptability of South Carolina kaolins to ceramic uses. The substitution of one clay for another in a test mix does not assure that the resulting product will produce the same results. Manufacturers through long experience have found that the substitution of a new clay is sometimes a hazardous undertaking and are loath to change unless forced to do so by necessity. However, the value of a new clay for substitution in a standard manufactured product or use in new products can be determined only by experiment and trial. Some South Carolina kaolins have physical properties that are relatively unique and may therefore offer possibilities that are being overlooked by those interested in the ceramic arts.

Of the 28 samples representing clays from the Tuscaloosa formation, 8 yielded white-ware disks of good white color, of which 2 (nos. 6 and 11) were characterized as very good or extremely good. Nine had fair white color, and 11 were rated as poor.

The three Piedmont samples serve to show the type of clay that may be found in selected areas in the Piedmont region bordering the Coastal Plain. These samples give good tests for white ware, and all have good color. Seldom are large uniform deposits of residual clay to be found, and except for ceramic uses their chance of introduction into industry appears slight. Where granitic areas rich in feldspar have been thoroughly weathered, as about Vaucluse, the rocks of the Piedmont consist of little more than white kaolin and quartz. Locally such exposures offer possibilities, but the extensive beds of grit-free kaolins in the Tuscaloosa, naturally selected, rather preclude development of the clay of the Piedmont except in rare circumstances.

SUPPLEMENTAL NOTE ON WATERS OF HORSE CREEK AREA

Aiken water supply.—During the months of March and April 1935 several water samples were taken to determine the characteristics of representative waters in the Horse Creek area.

Partial analyses of water from Aiken County, S. C.

[Analyzed by E. W. Lohr. Parts per million]

	1	2	3	4	5	6
Iron (Fe)	0.01	0.11	0.10	12.0	0.08	0.28
Bicarbonate (HCO_3)	3.0	1.0	2.0	16	3.0	26
Sulphate (SO_4) (by turbidity)	1	1	2	7	1	3
Chloride (Cl)	2.0	2.0	2.0	2.0	2.0	5.0
Nitrate (NO_3)	4.1	.15	.15	.10	.36	.20
Total hardness as $CaCO_3$	1.5	2	2	15	2	2
pH[1]	4.9	5.1	5.4	5.9	5.6	7.0
Date of collection (1935)	Mar. 14	Apr. 2	Apr. 4	Apr. 2	Apr. 1	Apr. 3

[1] Results less than 7 show degree of acidity.

1. Aiken public supply, collected from overflow of collecting basin at pumping plant.
2. Seepage from sands above clay bed in mine of South Carolina Clay Co. at Langley, S. C.
3. Seepage from sands above clay bed on the south wall of Alum pit of the Huber Corporation, south of Langley, S. C.
4. Seepage from sands above clay bed on north wall of Alum pit of the Huber Corporation, south of Langley, S. C.
5. Little Horse Creek near head, just below Beaver Creek, in northeastern quarter of the Warrenville quadrangle.
6. Horse Creek at Horse Creek crossing, 2½ miles northeast of confluence with the Savannah River.

Near Shiloh Church, 7 miles north of Aiken, is a small tributary drainage valley on the east side of Shaw Creek. Along the bottom of this valley issue a number of springs, the waters from which are now collected in an underground sump and conducted by a dual piping system to the Aiken pumping plant, three-eighths of a mile distant, by the Southern Railway right-of-way. The water (1 in preceding table) issues near the base of the Tuscaloosa formation. The natural collecting area covers many square miles between the South Fork of the Edisto River and Shaw Creek in the northwestern part of the Aiken quadrangle. Much of the water has traveled only within the Tuscaloosa, but part of it has also had to migrate through or along Barnwell beds. The springs yield on an average 2,000,000 gallons a day of clear and almost tasteless water, varying somewhat in amount with the seasons. When drawn from taps in Aiken the water has a very strong iron flavor. This is due to the acid in the water, which has dissolved sufficient iron in its travel through the piping system to acquire this pronounced flavor. Waters of this character are highly corrosive to water-supply systems.

South Carolina Clay Co.—A sample of ground-water seepage (2) was taken from the base of the overlying sands above the clay bed of the South Carolina Clay Co. The water has passed through red Barnwell and upper Tuscaloosa deposits before appearing on the surface. The solution of iron undoubtedly occurs during percolation through the Barnwell, and precipitation takes place shortly after exposure to the open air.

Alum pit, Huber Corporation.—A similar sample of water (3) was taken at the base of the south wall of sands overlying the clay bed in the Alum pit of the Huber Corporation. The stratigraphic position is the same as that of sample 2 and represents waters which have percolated through the overlying Tuscaloosa sands and Barnwell formation. These two samples of water are fairly representative of the character of waters to be found in the overburden of the Aiken County clay pits.

A sample (4) was also taken from a seep on the north wall of the Alum pit of the Huber Corporation. At many localities seepage water in the clay pits and outcrops coats the surfaces over which it flows with a rich brown iron deposit. This water was crystal clear as it issued from a seam above the top of the clay. Permitted to stand for a few minutes it became cloudy, and after half an hour it had precipitated a heavy iron sediment. It is this iron sediment that streaks the walls of many clay pits and covers the bottoms of settling basins. Oxidation of the ferrous iron to the ferric state is the cause of the precipitate.

Little Horse Creek.—Little Horse Creek was sampled (5) near its head, immediately below the junction with Beaver Creek, in the northeast quarter of the Warrenville quadrangle. This is an uncontaminated flow of water that is representative of ground waters issuing from the Tuscaloosa formation. The estimated flow is 0.10 second-foot. The water is clear but carries a minute quantity of organic material, leaf fragments, etc., which serve to increase the acidity of the water.

Horse Creek.—A sample of Horse Creek water (6) was taken at Horse Creek crossing, 2½ miles northeast of the Savannah River, into which it flows. The sample was taken April 3, 1935, after a heavy rain, so that unfortunately the dissolved constituents had been partly diluted. Although at the place where the sample was taken the creek is carrying disposal waters from clay plants and cotton mills, the character of the water has not been greatly altered, as may be seen by comparison with analysis 5 which represents the source of the stream. The acidity so prominent in all the other waters has been neutralized. The estimated flow is 60 second-feet.

These samples serve to show the acid character of the highland ground waters of the Coastal Plain deposits and their potential leaching power. They may accomplish very little solution, because the sedimentary deposits through which they flow are already thoroughly leached. The only carbonate rocks of the Coastal Plain in the area discussed are the Barnwell buhrstones, which have been almost completely silicified.

To what extent the present color of the kaolins is primary is a question. No doubt there have been alterations of greater or less extent. The more prominent changes are probably due to the local concentration or alteration of coloring matter in the clay. The accumulation of larger beds of fine white kaolin or of beds of clay having desirable physical properties seems to be more directly related to the source material from which the Tuscaloosa clays were derived than to any alteration subsequent to deposition. There is, however, a current opinion among mine operators that a kaolin bed improves in whiteness beneath a hill slope after removal of the outer discolored clays, but that with continued penetration beneath a thickening overburden it becomes more grayish and duller in appearance. If such is truly the fact, the cause for such a change may have its origin in the action of acid ground water, which could more readily percolate through the marginal portion of a clay bed than within the mass.

CHAPTER 3.—THE BLEACHING CLAYS OF SOUTH CAROLINA

BY HARRY X. BAY

INTRODUCTION

Part of the Public Works funds allocated to the Geological Survey for work on South Carolina clays was devoted to a reconnaissance investigation of bleaching clays. Little published information on this subject was then available, though Sloan [51] had briefly described some occurrences of fuller's earth. Cooke [52] had mentioned similar occurrences, in his manuscript on the South Carolina Coastal Plain which has since been published. Information was accordingly sought regarding the occurrence, extent, quality, and possible commercial importance of bleaching clays, in the hope that some discovery might be made that would lead to the establishment of a new industry in the State.

SCOPE AND METHODS OF THE INVESTIGATION

Representative exposures of all formations cropping out within the Coastal Plain area were examined for possible occurrences of bleaching clay and for readily available data regarding those of greatest promise. Beds ranging in age from Cretaceous to Pleistocene were studied. The formations and the areas in which they were explored are summarized below. Detailed information regarding these formations and their distribution is given in Cooke's report just cited.

Formations and counties included in investigation

Formation	Counties
Pleistocene undifferentiated	Chesterfield, Horry, Kershaw.
Hawthorn formation (Miocene)	Hampton.
Barnwell sand (Eocene)	Aiken, Barnwell, Lexington.
McBean formation (Eocene)	Aiken, Calhoun, Lexington, Orangeburg.
Black Mingo formation (Eocene)	Calhoun, Clarendon, Georgetown, Richland, Sumter, Williamsburg.
Black Creek formation (Upper Cretaceous)	Darlington, Florence, Marion.
Tuscaloosa formation (Upper Cretaceous)	Aiken, Chesterfield, Darlington, Kershaw, Lexington, Marlboro, Richland.

Numerous exposures of the outcropping formations were examined and prospected with a 3-inch cup auger of Iwan Bros. type. Many

[51] Sloan, Earle, A preliminary report on the clays of South Carolina: South Carolina Geol. Survey Bull. 1, pp. 59–61, 1904; Catalogue of the mineral localities of South Carolina: South Carolina Geol. Survey Bull. 2, 1908.

[52] Cooke, C. W., Geology and mineral resources of the Coastal Plain of South Carolina: U. S. Geol. Survey Bull. 867, p. 160, 1937.

samples were collected and later tested in the laboratories of the Geological Survey under the direction of P. G. Nutting, whose method of testing the samples is described in chapter 1 of this volume. The field work was done under the general supervision of C. Wythe Cooke.

GENERAL RESULTS

The results of this preliminary study strongly suggest that no bleaching clays of much commercial importance occur within the State. Several samples from the Tuscaloosa, Black Mingo, and McBean formations proved to be low-grade fuller's earths somewhat active in the natural state, but these are exceptional. Only a few samples even from these formations were sufficiently active to qualify as commercial bleaching clays.

Local deposits of clay in the Barnwell sand meet commercial requirements and compare favorably with different naturally active clays now being mined and marketed elsewhere. These deposits, however, are too small to support large mining operations.

The localities from which samples were collected for testing are shown on plate 1.

The following table gives detailed information concerning the samples tested and the results:

LOCATION AND RESULTS OF TESTS

Tests of South Carolina clays as bleaching clays

Tuscaloosa formation (Upper Cretaceous)

County	Location	Description	Bleach rating: Raw G	Raw Y	Raw R	Raw B	Acid-treated G	Acid-treated Y	Acid-treated R	Acid-treated B	Remarks
Chesterfield	100 feet north of mess hall at Boy Scout camp 5 miles west of Society Hill.	3-foot exposure of white, soft, massively bedded, very sandy kaolinitic clay.	0.5	0.6	0.6	0.6	0.6	0.7	0.8	0.8	Not of commercial interest.
Aiken	E. J. Siegler property, 10 miles east of Aiken, south end of fishing lake.	*Feet* Sand, brown, fine-grained ... 3 Clay, white to light gray, micaceous, sandy, kaolinitic ... 3 Clay, kaolinitic, interlaminated with coarse-grained sand ... 4 Sand at base, mottled brown and gray, coarse-grained. 10	.6	.7	.8	1.0	.7	.8	.9	1.0	Sample represents clay members; not of commercial interest.
	Road cut 2.2 miles east of Aiken on "Two Notch" road.	2-foot exposure of clay, white, iron-stained, slightly sandy, plastic and and kaolinitic. Overlain by red and brown clayey fine- and medium-grained sand.	.6	.7	.8	.9	.6	.8	.9	.9	Not of commercial interest.
	Road cut 5.2 miles southeast of Monetta on State Highway 39.	Small pocketlike lens of clay, purplish and light gray, micaceous, finely sandy, and kaolinitic. Overlain by red friable clayey fine-grained sand.	1.0	1.1	1.2	1.3	.8	.9	1.0	1.2	A low-grade fuller's earth in raw state. Deposit too small to have commercial interest.
	O. L. Courtney farm, 4.3 miles northeast of Aiken.	3-foot exposure of clay, light gray to white, partly silicified, slightly micaceous, and finely sandy; underlain by kaolin.	.7	.8	.9	1.1	1.0	1.2	1.2	1.3	Not commercial.
	Road cut, 10.0 miles northwest of Wagener on State Highway 39.	Clay bed forms hard ledge of claystone, light gray to white, slightly micaceous, somewhat sandy; maximum thickness 3 feet.	.6	.7	.8	.8	.8	.9	1.0	1.1	Do.
Richland	Abandoned clay pit 2½ miles east of Killian.	10-foot exposure of clay, light gray and white, slightly micaceous and sandy, kaolinitic; overlain by brown friable clayey sand.	.5	.6	.7	.7	.5	.6	.7	.8	Do.

Tests of South Carolina clays as bleaching clays—Continued

Black Creek formation (Upper Cretaceous)

County	Location	Description	Bleach rating: Raw G	Raw Y	Raw R	Raw B	Acid-treated G	Acid-treated Y	Acid-treated R	Acid-treated B	Remarks
Florence	Mars Bluff on Pee Dee River 10 miles east of Florence on United States Highway 17.	*Feet* Clay, yellow, sandy — 9 Clay, mottled brown, red and yellow, grading to pebbly sand at base — 8 Sand, yellow, medium-grained, interlaminated with black carbonaceous clay — 6 Clay, black, carbonaceous, sandy, partly silicified, with interbedded clayey sand; base not exposed — 10 33	0.5	0.6	0.7	0.7	0.8	1.2	1.3	1.4	Rating given is for lowest bed. Not commercial.
Darlington	Bank of Black Creek, 1.2 miles east of Darlington on Mechanicsville road.	5 feet of shale, black, carbonaceous, thinly laminated, slightly sandy, exposed above water level.	.6	.6	.6	.6	.9	.9	.9	.9	Not a bleaching clay.
Sumter	Cut on Southern Ry. 1.1 miles west of Wedgefield.	*Feet* Greensand, coarse, interlaminated with gray clay, orange and yellow sand — 11 Clay, sandy and pebbly — 2 Arkosic sand and clay — 2 Clay, mottled purplish and gray, pyritic. 15	.5	.6	.7	.7	.6	.7	.8	1.0	Sample represents middle of top bed. Not a bleaching clay.

Black Mingo formation (Eocene)

County	Location	Description	Raw G	Raw Y	Raw R	Raw B	Acid-treated G	Acid-treated Y	Acid-treated R	Acid-treated B	Remarks
Sumter	Road cut about 9 miles south of Wedgefield on Rimini road.	15 feet of claystone, indurated, light to dark gray, brittle, siliceous. Sample 1, 5 feet from top; 2, 10 feet from top; 3, 15 feet from top.	(1)0.5 (2) .6 (3) .6	0.6 .8 .7	0.7 .9 .8	0.9 1.1 1.1	0.6 .6 .7	0.8 .8 .9	1.0 1.0 1.1	1.1 1.3 1.3	Samples 2 and 3 approach lowest limit permissible for commercial clays but are not sufficiently active to be of interest.

	Ravine just north of U. S. Highway 76 at Holy Cross Church, 1 mile west of Stateburg.	A 5-foot bed of clay, light to dark gray, massively bedded, slightly micaceous, brittle unctuous; underlain by inter-laminated clays and sands.	.6	.7	.8	1.0	.6	.9	1.1	1.3	Sample from middle of bed; not commercial.
	Cut on Southern Ry. 0.9 mile west of Wedgefield.	*Feet* Clay, red, sandy, pebbly ... 15 Sand, gray, clayey, coarse ... 10 Clay, tan to buff, hard and brittle, slightly micaceous and sandy; conchoidal fracture ... 10 Sand and clay, brownish gray interlaminated ... 35	.6	.8	.9	1.0	.5	.6	.7	.9	Sample from middle of tan-colored bed; not commercial.
	At Moore's Spring, about 200 feet west of Stateburg Road, 2.2 miles north of Wedgefield.	12 feet of shale, tan and gray, laminated, sandy, with interstratified sand and mica.	.4	.5	.6	.6	.6	1.0	1.3	1.7	Sample from middle of exposure; not suitable for bleaching oils.
	Road cut 1 mile north of Stateburg on Camden road.	4 feet of clay, light gray, unctuous, slightly sandy, in ditch by roadside, associated with ferruginous clayey sand.	.5	.7	.8	.8	.5	.7	.9	1.2	Sample from middle of bed; not commercial.
Clarendon ...	Tindall's mill at Sammy Swamp, 2.9 miles east of Paxville on Manning road.	Clay, black, waxy, unctuous, slightly micaceous, seen only as float at water's edge.	.4	.5	.5	.5	.5	.8	.9	1.4	Not suitable for bleaching oils.
Williamsburg ...	River bluff at Rock Hole, 100 yards below highway bridge over Black River at Kingstree.	Several feet of shale, black, with fine micaceous partings. Total thickness not known.	.5	.5	.5	.5	.6	1.0	1.2	1.6	Not commercial.
	Black River bridge on State Highway 521, 1.8 miles southeast of Salters, 6 miles southwest of Kingstree.	*Feet* Sand, red, fossiliferous, coarse ... 6 Sand, yellow, pebbly, coarse ... 3 Clay mottled red, yellow, and gray; plastic, sandy ... 3 Sand, yellowish to brown; medium ... 1 Clay, light to dark gray, laminated, unctuous; partings of fine micaceous sand; partly silicified ... 14 27	.6	.9	1.1	1.1	.4	.5	.8	1.3	Sample from middle of 14-foot bed. Almost reaches lowest commercial limit; reached highest bleach rating of all samples from Black Mingo formation; not commercial.

Tests of South Carolina clays as bleaching clays—Continued

McBean formation (Eocene)

County	Location	Description	Bleach rating								Remarks
			Raw				Acid-treated				
			G	Y	R	B	G	Y	R	B	
Calhoun	Road cut at Warley Hill, just east of Stouts Creek and 6.5 miles southeast of Fort Motte.	15 feet of shale, greenish gray, semiplastic, obscurely laminated, unctuous, upper and lower parts more or less silicified.	0.6	0.7	0.8	0.9	0.6	0.9	1.0	1.4	Sample from middle of section; not commercial.
	Road cut 1.5 miles north of Warley Hill on Fort Motte road.	*Feet*									Sample from middle of middle bed is a low-grade fuller's earth but is poorer than most clays now marketed and hence is of doubtful interest commercially.
		Sand, red and brown, clayey, fine to coarse 6									
		Shale, light gray, unctuous, hard, brittle, conchoidal, thin-bedded 8	.6	.8	.9	1.3	.6	.8	.9	1.1	
		Clay, very dark gray, unctuous, hard, brittle, thick-bedded 1	.6	.8	.9	1.1	.6	.8	.9	1.3	
		15									
	Road cut at Calvary Church 3.5 miles north of St. Matthews and just south of High Hill Creek.	20 feet of claystone, bluish-gray, porous, slightly carbonaceous, hard, brittle, bedded. Sample 1, 3 feet from top; sample 2, near middle.	(1).6 (2).7	.7 .9	.9 1.1	1.2 1.3	.7 .7	.9 .9	1.0 1.0	1.3 1.3	Low-grade fuller's earth, of doubtful commercial interest.
Orangeburg	Road cut 4.8 miles north of Orangeburg on Columbia road.	4 feet of clay, light gray, slightly sandy, fossiliferous, calcareous.	.4	.6	.7	1.1	.3	.4	.6	1.1	Not commercial.
Aiken	Road cut 3.2 miles west of Wagener on State Highway 39.	Clay, thin lens, mottled purplish and pinkish gray, finely micaceous, slightly sandy, kaolinitic; very small deposit.	.6	.7	.8	.8	.8	.9	1.0	1.1	Do.

Barnwell sand (Eocene)

Aiken	Property of Wayne Gunter, at Three-Cornered Pond, 2 miles west of Seivern.	8 feet of claystone, buff to light gray, slightly micaceous and sandy, conchoidal fracture. Covered and underlain by indurated fine to medium sand. Sample 1, 2 feet from top; sample 2, 1 foot from base.	(1) 0.6 (2) .6	0.8 .9	0.9 1.0	1.1 1.2	0.5 .7	0.7 .9	0.8 1.0	1.0 1.2	Lower part a low-grade fuller's earth, upper part poorer. Of little commercial interest. Freshly exposed claystone may be sawed and shaped with ordinary tools; has been locally used on considerable scale for chimney construction.
	Property of William Taylor, 4.2 miles east of Aiken on State Highway 215. Small deposit caps hill about a quarter of a mile north of house. Nearest railroad at Aiken, 4.5 miles.	Claystone, fairly hard, brittle, porous, slightly sandy; overlies soft, white, kaolinitic clay. Two beds together 5 feet thick. Overburden clayey sand about 25 feet thick (maximum). Sample 1, hard claystone; sample 2, soft layer.	(1) 1.0 (2) .9	1.2 1.1	1.3 1.2	1.5 1.5	.9 .9	1.1 1.1	1.2 1.2	1.4 1.3	Fuller's earth comparable with that being commercially produced from the Barnwell in central Georgia. Size and thickness of deposit unfavorable for commercial development.
	Property of Mrs. Vesta Johnson, 7 miles northeast of Aiken on Two Notch Road 7 miles from railroad at Aiken.	Clay deposit about 30 acres extending north of dwelling. Thickness 12 feet at north to 4 feet near house. About 20 acres has overburden over 50 feet thick. Clay is light gray to tan and buff, hard, brittle, slightly micaceous and sandy; has conchoidal fracture; lower part commonly interlaminated with yellowish and brown, fine sand. Samples 1–3 from 12-foot exposure at north represent top, middle, and bottom of clay. Samples 4–8 from 9-foot thickness: 4, 1 foot from top; 5, 3 feet from top; 6, 5 feet from top; 7, 7 feet from top; 8, at base.	(1) 1.1 (2) .7 (3) .6 (4) .9 (5) .7 (6) .7 (7) .6 (8) 1.0	1.4 .8 .8 1.0 1.0 .9 .8 1.2	1.6 .9 .9 1.2 1.2 1.0 .9 1.4	1.8 1.2 1.2 1.2 1.4 1.2 1.1 1.7	.9 1.0 .7 .9 .9 .8 .8 .6	.9 1.2 1.0 1.3 1.1 1.1 1.1 .8	1.0 1.3 1.2 1.6 1.2 1.3 1.2 1.0	1.2 1.5 1.4 1.8 1.4 1.5 1.4 1.4	Some samples of commercial grade, but average not high, and quality varies irregularly. Samples 1, 5, and 8 are the best. Middle of deposit poor. Variation in quality and distance from railroad unfavorable for exploitation of deposit.
	Property of Dr. M. J. Quattlebaum, 4.5 miles northeast of Aiken on U. S. Highway 1 and 0.5 mile east on local road. Nearest railroad at Aiken, 5 miles.	7 feet of clay, brownish to greenish gray, conchoidal, hard and brittle, slightly sandy and micaceous; lies in valley of small stream; covers about 10 acres mostly swamp. Overburden thin mantle of red and brown clayey sands. Samples 1–3 from bed causing waterfall (1, top; 2, middle; 3, base). Samples 4–6 from auger hole 100 yards north of waterfall (4, top; 5, 3 feet from top; 6, base at 6 feet). Samples 7–9, top, middle, and bottom of auger boring in 4-foot layer at north end of deposit.	(1) 1.0 (2) .9 (3) .9 (4) 1.1 (5) .9 (6) .7 (7) .6 (8) .5 (9) .6	1.2 1.2 1.2 1.3 1.1 .9 .7 .6 .8	1.3 1.3 1.3 1.4 1.2 1.0 .7 .6 .9	1.5 1.5 1.5 1.6 1.4 1.2 .8 .6 1.0	.6 .8 .9 1.0 .7 .9 .6 .8 .9	1.0 1.1 1.1 1.2 .9 1.1 .8 1.1 1.2	1.3 1.4 1.2 1.3 1.1 1.3 .9 1.2 1.3	1.5 1.8 1.5 1.5 1.3 1.4 1.1 1.4 1.5	Southern part of deposit good fuller's earth of consistent quality, but only 3 or 4 acres, partly covered by swamp. Small area of good material and distance from railroad makes deposit commercially unattractive.

Tests of South Carolina clays as bleaching clays—Continued

Barnwell sand—Continued

County	Location	Description	Bleach rating								Remarks
			Raw				Acid-treated				
			G	Y	R	B	G	Y	R	B	
Allendale	Road cut just south of Martin on State Highway 28.	3 feet of clay, gray, ironstained, thinly laminated, finely sandy, associated above and below with red and brown fine sand.	.7	.9	1.0	1.0	.7	.9	1.0	1.1	Not commercial.
Lexington	Property of Elmore Williams, 0.8 mile west of Gaston.	About 8 feet of claystone, light gray, porous, brittle, slightly micaceous and sandy, exposed at several places in valley of First Creek. Overlain by thick beds of quartzitic and ferruginous sand. Sample from middle of bed.	.7	.8	1.0	1.1	.7	.8	1.1	1.3	Low-grade fuller's earth; not commercial.
	Property of Elmore Smith, 3 miles southeast of Leesville. Section in hills bordering Hell Hole Branch.	*Feet* Sand, white to gray, arkosic coarse; contains some admixed kaolinitic clay and is locally quartzitic ---- 12 Clay, kaolinitic, white, partly silicified ---- 8 —— 20 Sample taken near top of clay bed.	.6	.7	.8	.9	.6	.7	.8	1.0	Not commercial.
	Zid property, 3 miles southeast of Gaston, on west side of Sandy Run. Clay crops out on side hill.	6 feet of clay, light gray, more or less indurated, sandy and micaceous; interlaminated micaceous sand. Overburden sand and sandy clay, maximum about 50 feet. Sample from middle of clay bed.	.7	.9	1.1	1.2	.7	.9	1.0	1.1	Clay is lowest commercial grade of fuller's earth. Thick overburden, small size of deposit, distance from railroad, and poor roads render deposit noncommercial.
	J. L. Lucas place, 2.3 miles east of Sharp Hill School, about 12 miles east of Pelion.	5 feet of claystone, white, indurated, sandy, silicified, exposed in old road. *Extent not determined.*	.5	.7	.8	1.0	.7	.9	1.0	1.1	Not commercial.

	John Sanchen property, ¼ mile east of Harmony Church, 9.2 miles east of Pelion.	Claystone, tan and gray, indurated, porous, brittle, slightly sandy; breaks with conchoidal fracture. Exposed only as float over considerable area of large hill.	1.1	1.3	1.4	1.5	.8	1.0	1.2	1.5	Natural bleach rating fairly high. Extent not known. Distance from railroad (12 miles) would hinder exploitation, even if deposit were large.
Hawthorn formation (Miocene)											
Beaufort	Huspe Creek bridge on Coosaw road, 1 mile east of Sheldon.	Clay, dark to yellowish brown, indurated, slightly glauconitic, silicified. Exposed by low tide in bed of creek. Sample from top.	0.9	1.0	1.0	1.0	0.3	0.6	0.8	0.9	Not commercial.
Pleistocene											
Chesterfield	Cedar Creek, just north of Society Hill on State Highway 601.	4 feet of clay, mottled dark gray and brown, sandy. Sample from middle of exposed bed.	0.5	0.6	0.7	0.8	0.9	1.2	1.5	1.7	Not commercial.
Darlington	Road cut near Darlington veneer mill, southern part of town.	3 feet of clay, mottled pink and light gray, finely sandy and micaceous. Sample from middle of exposure.	.3	.4	.4	.4	.5	.7	.8	.9	Do.
Georgetown	Auger boring 5.6 miles east of Andrews on U. S. Highway 521.	12 feet of clay, mottled tan and bluish gray, plastic, sandy. Sample 4 feet from top.	.6	.7	.8	.8	.7	1.0	1.3	1.6	Do.
Horry	Auger boring 2.4 miles north of Conway on U. S. Highway 701, at Brown Swamp.	11 feet of clay, mottled gray and brown, plastic, essentially free from sand. Sample from middle of bed.	.6	.7	.8	.8	.9	1.2	1.4	1.6	Do.
Kershaw	Abandoned clay pit 3.5 miles south of Camden, about 100 yards east of paved road.	5 feet of clay, light to dark gray, plastic, slightly sandy, exposed on wall of pit. Sample from middle of bed.	.5	.7	.7	.8	.5	.8	.9	1.0	Do.
Marlboro	Clay pit 1.5 miles north of Cheraw on State Highway 9.	8 feet of clay, mottled light and dark gray, tough, plastic, slightly sandy, exposed in wall of pit. Sample from middle of exposure.	.5	.6	.7	.8	.7	1.0	1.2	1.3	Do.

SUMMARY AND CONCLUSIONS

Formations ranging in age from Upper Cretaceous to Pleistocene were examined for possible deposits of bleaching clay. Numerous samples were collected and tested for both naturally active and activable bleaching properties. The only bleaching clays found were those of the naturally active type.

Fuller's earth was found in the Tuscaloosa (Upper Cretaceous), Black Mingo (Eocene), McBean (Eocene), and Barnwell (Eocene) formations. In all except the Barnwell the bleaching clays are very inferior in quality and occur in very small deposits.

Several small deposits of fuller's earth are found in the Barnwell formation in Aiken and Lexington Counties. The deposits are not readily accessible, and the quality of the clay is variable. It is doubtful if these deposits are worthy of commercial attention.

This investigation failed to reveal extensive deposits of high-grade bleaching clay in South Carolina.

CHAPTER 4.—CLAY DEPOSITS OF THE SAN ANTONIO AREA AND MORRIS COUNTY, TEXAS

By PHILIP B. KING

INTRODUCTION

In the San Antonio area, which includes Bexar and surrounding counties, in the central part of Texas, clays are an important natural resource. North and west of San Antonio the rocks are largely limestones and chalks, clays being subordinate or not of commercial quality. South and east of San Antonio, however, beginning with the highest two formations of the Cretaceous and extending into the Eocene, clay is an abundant constituent of the rock succession. It is in this part of the San Antonio area that clay deposits of commercial value are found. (See pl. 4.) Here most time was spent in the present investigation.

Clays found in the San Antonio area have two chief uses. The greater number may be used for ceramic purposes—that is, for the manufacture of brick, tile, and pottery. A lesser number, having special properties, may be used for bleaching or clarifying petroleum and vegetable oils.

The purpose of this report is to record the extent and quality of the various types of clays in the region. Notes are given on their field relations and geologic character, and a series of chemical and physical analyses of the samples is presented. Some of the deposits are described in detail, but others only in a general way, as lack of time prevented all from being studied with care. The writer is informed that on some of the deposits, commercial organizations have done much detailed prospecting, the results of which have not been published. Despite the limitations of the present report, it is hoped that it may be a guide to anyone who may wish to develop clay deposits in the area.

Field work.—The field work on which this report is based was carried out under funds provided to the Geological Survey by the Public Works Administration. Four months was spent in field work by the writer, and 3½ months by his assistants. H. C. Fountain served as geologic assistant, and J. R. Martin, Jr., and C. P. Rogers as rodmen.

At the beginning of the work the writer received geologic guidance in the field from L. W. Stephenson, of the Geological Survey, and somewhat later the ceramic engineering aspects of the problem were reviewed in the field with David McKnight, Jr., of the Bureau of Industrial Chemistry, University of Texas.

During the course of the field work reconnaissance surveys were made by the writer, and detailed prospecting of selected areas was done by his assistants. Most of the time was spent in Bexar County and areas immediately adjacent. The observations on the bleaching clays of the upper Claiborne and Jackson deposits are based on the writer's reconnaissance trips alone, as time did not permit the assistants to do detailed work in that area.

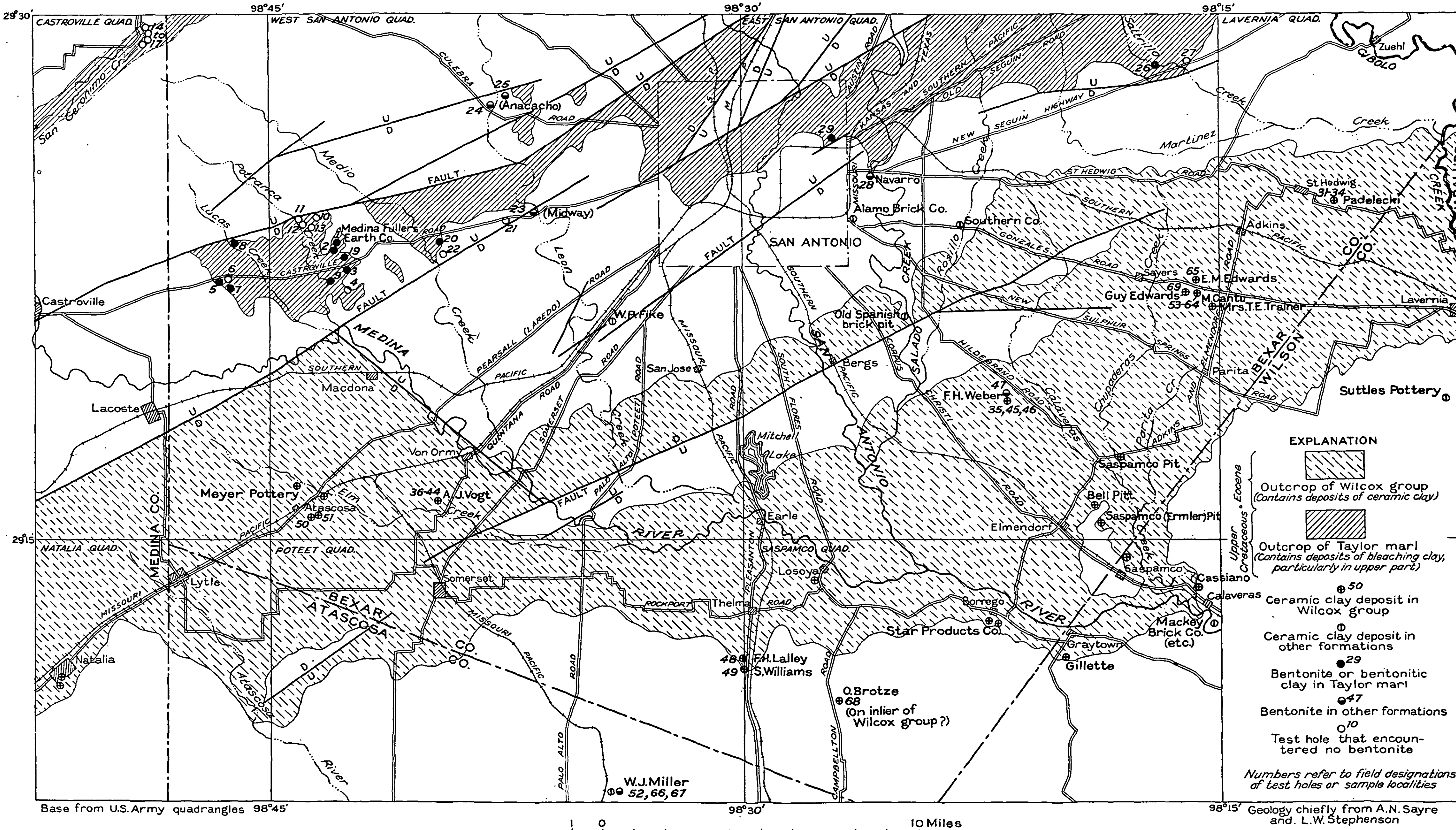
The chief duties of the assistants consisted of gathering clay samples for testing. For this purpose surface exposures were examined where possible, and in some places shallow pits were dug. The greater number of samples were obtained, however, by drilling auger holes, this type of work being well adapted to the unconsolidated nature of the bedrock.

Two types of augers were used. One type, a post-hole hand auger, had a bit with a cutting edge at one end and a cross-bar handle at the other. As a hole was deepened, lengths of pipe were added between the two ends. This method proved particularly effective for depths of less than 25 feet, but beyond that depth the amount of labor involved became prohibitive because of the unwieldiness of the tool and the necessity of raising it at frequent intervals to empty the cuttings. The other type, a drop auger, had a cylindrical bit, lowered into the hole by a rope which ran through a pulley. Drilling was accomplished by dropping the heavy tool in the hole and gathering the cuttings inside the cylinder. Although a tool of this type proved difficult to use at shallow depths, it had many advantages. Drilling through hard beds was relatively easy, the samples recovered were in large pieces, and considerable depths could be attained without an increase in the difficulty of the work. The deepest test hole put down was somewhat more than 70 feet deep.

Much difficulty was encountered in prospecting the low country underlain by the Taylor marl because almost the whole surface is covered by a veneer of limestone and chert gravel from a few feet to tens of feet thick. Holes could not be put through the gravel with either type of auger, so that at several places it was necessary to dig a pit through the gravel and start an auger hole in its bottom. In the formations farther east and south of San Antonio the gravel cover is less extensive and over wide areas is lacking entirely.

The bleaching-clay samples collected were tested by P. G. Nutting, of the Geological Survey. The ceramic-clay samples were studied under the direction of David McKnight, Jr., of the Bureau of Industrial Chemistry, University of Texas.

Previous work.—Several reports have been published on the geology of the region. General descriptions of the geologic formations are



GEOLOGIC MAP OF SAN ANTONIO AREA, TEX., SHOWING LOCATION OF CLAY DEPOSITS.

given by Deussen [53] and Plummer,[54] and a more detailed account of the geology of Bexar County by Sellards.[55] Recently the geology and ground-water resources of Bexar County have been studied for the Geological Survey by A. N. Sayre and Penn Livingston, and their report will be published as a water-supply paper.[56] Notes and maps made for this work were available to the writer and were of great value in the present investigation.

Several publications on Texas clays give information on the San Antonio area. A general study in the field and laboratory was made by Ries [57] in 1903. The Bureau of Industrial Chemistry of the University of Texas, under the direction of Dr. A. P. Schoch, has been interested in the development of Texas clays and the results of their tests, made over a considerable period of years, were summarized by Potter and McKnight in 1931. Another investigation, made for the San Antonio Chamber of Commerce by A. V. Lawton, relates more directly to the San Antonio area. A summary of its results has been published in pamphlet form.[58] Through the courtesy of Mr. C. C. Leel, industrial secretary of the organization, the detailed results of this work were placed at the writer's disposal.

These three publications deal chiefly with ceramic clays. Very little has been published on the bleaching of clays of Texas, although a great deal of development work has been done, and much information is doubtless on file with the various companies engaged in the business. Incidental mention of bleaching power is made in descriptions of some of the clay deposits in the three reports cited, but these descriptions deal chiefly with their ceramic properties. A paper by Broughton [59] describes the detailed petrographic properties of clays from the most important deposits. This was an outgrowth of an extensive field study of the deposits by J. T. Lonsdale, of Texas Agricultural and Mechanical College, but his results have so far not been published. A paper

[53] Deussen, Alexander, Geology of the Coastal Plain of Texas west of the Brazos River: U. S. Geol. Survey Prof. Paper 126, 1924.

[54] Plummer, F. B., Cenozoic systems, in The geology of Texas, vol. 1, Stratigraphy: Texas Univ. Bull. 3232, pp. 519–808, 1933. See also, Darton, N. H., Stephenson, L. W., and Gardner, J. A., Geologic map of Texas: U. S. Geol. Survey, 1937.

[55] Sellards, E. H., The geology and mineral resources of Bexar County: Texas Univ. Bull. 1932, 1920.

[56] For a preliminary account, see Livingston, Penn, Sayre, A. N., and White, W. N., Water resources of the Edwards limestone in the San Antonio area, Tex.: U. S. Geol. Survey Water-Supply Paper 773–B, pp. 59–113, 1936.

For water supply papers on adjoining counties, see Sayre, A. N., Geology and ground-water resources of Uvalde and Medina Counties, Tex.: U. S. Geol. Survey Water-Supply Paper 678, 1936. Lonsdale, J. T., Geology and ground-water resources of Atascosa and Frio Counties, Tex.: U. S. Geol. Survey Water-Supply Paper 676, 1935.

[57] Ries, Heinrich, The clays of Texas: Texas Univ. Bull. 102 (Sci. ser., no. 12), 1908. The results are also summarized in Potter, A. D., and McKnight, David, The clays and ceramic industries of Texas: Texas Univ. Bull. 3120, pp. 168–175, etc., 1931.

[58] Physical tests on more than 400 clays of south and southwest Texas, San Antonio Chamber of Commerce, 1929. The results are also summarized in Potter, A. D., and McKnight, David, op. cit., p. 216 and table 7.

[59] Broughton, M. N., Texas fuller's earths: Jour. Sedimentary Petrology, vol. 2, pp. 135–139, 1932.

by Phillips and Phillips [59a] describes methods of producing and using the Texas bleaching clays and gives brief notes on their occurrence.

Acknowledgments.—The writer wishes to acknowledge the assistance which the reports cited above have furnished. In some places the published reports furnish valuable information supplementary to that obtained in the present work, and such information has been quoted in this report.

In addition to the published information regarding the clays of the San Antonio area, much unpublished information exists, and the writer wishes to acknowledge the courtesies shown by many local people in obtaining such information.

Mr. John Randolph Martin, of San Antonio, gave the location of many deposits where promising clays have been found, and furnished samples of some of them. Mr. W. S. Hamilton, of the Earthern Products Co., and Mr. D. M. Phillips, of the Texas Co., guided the writer through the pits operated by their companies and furnished many supplemental notes. Mr. H. B. Parks, of the Texas Apicultural Experiment Station, who has spent much time in a study of the geology of southern Bexar County, gave information on exposures and clay occurrences which otherwise might not have been found.[60] Local geologists, both with the Texas Bureau of Economic Geology and with oil companies, furnished information. In particular, Messrs. B. C. Renick and Stuart Mossom, of the Magnolia Petroleum Co., aided greatly in establishing the exact stratigraphic horizon and the position by land surveys of the clay deposits of Claiborne and Jackson age.

GENERAL GEOLOGIC RELATIONS

The geologic structure of the San Antonio area has an important bearing on the distribution of the various clay deposits, and has been well described in geologic reports.[60a]

According to Sellards,

> The formations in Bexar County, both those of the Cretaceous and Tertiary, dip toward the Gulf coast. The rate of dip, however, is changed, and the country is divided both structurally and physiographically into two very distinct provinces along the * * * Balcones escarpment, which in this country faces south-southeast. * * * The structure in the Coastal Plain area of this county is much more complicated than is that north of the Balcones escarpment, being affected both by faulting and by folding. At the inner or north margin of the Coastal Plain area are large faults, while farther south are other faults varying from small to large, accompanied by folds. The downthrow in most, although not in all, of

[59a] Phillips, D. M., and Phillips, L. V., Production and utilization of Texas bleaching clays: Texas Univ. Bull. 3501, pp. 105-111, 1935.

[60] Some of Parks' observations have since been published. See Parks, H. B., and Kirn, A. J., Old and new fossil localities in Bexar County and adjacent areas: Texas Acad. Sci. Trans., vol. 18, pp. 11-16, 1936. Kirn, A. J., and Parks, H. B., An Eocene florule near Lytle, Tex.: Texas Acad. Sci. Trans., vol. 19, pp. 11-17, 1936.

[60a] Sellards, E. H., op. cit., pp. 77-86. Deussen, Alexander, op. cit., pp. 20, 129-136. Livingston, Penn, Sayre, A. N., and White, W. N., op. cit., pp. 68 and 71-72.

the faults * * * is to the southeast or coastal side. * * * The combined effect of faulting and dipping, although varying from place to place, results on the whole in carrying the formations rapidly to a lower level in passing toward the coast.

As a result of these structural relations, the clay-bearing formations of the San Antonio area crop out in general in long, narrow northeastward-trending belts. Their inclination is to the southeast, so that in a distance of several miles in this direction any workable bed will be carried too far below the surface to be dug profitably. In places also the outcrops of the clay-bearing formation are cut off abruptly by faults, movement along which has either raised them so high that they have been carried away by erosion, or lowered them so far that they cannot be reached by ordinary processes of digging.

CERAMIC CLAYS

PRODUCTION AND USE

Clays have long been in use for ceramic purposes in the San Antonio area. Without doubt, pottery was manufactured on a small scale by the earliest Mexican settlers, and similar ware is still made by local people of Mexican descent. Extensive deposits have never been opened up for this purpose, and the craftsmen have usually contented themselves with digging small quantities of clay from the surface.

One of the oldest localities for brick manufacture is apparently that which lies southeast of San Antonio on the west bank of Salado Creek south of the Upson Road (plate 4 [61]). A brick plant is said to have been operated here as late as the 1890's, but the first use of the deposit was during the building of the San José and other Spanish missions. Old bricks now lying about near some of the ruined kilns are stamped with Roman numerals and are said to be of the type used in the construction of the missions.

Another deposit that has been worked for a long time is that at the village of Calaveras, in Wilson County, not far from the Bexar County line. Bricks were produced here as late as 1915, but the earliest production was probably in the 1860's. It is on record that in 1870 Antonio García purchased a tract at this place on which there was already a kiln and a pug mill. Many of the old landmarks of the region, such as the Menger Hotel, in San Antonio, and the Flores house, in the southeastern part of the county, were built of brick from Calaveras.

In the last 20 years several brick and hollow-tile plants have been established near San Antonio, but many of these were shut down or

[61] In this report the detailed location of the clay deposits is usually given in terms of their distance and relations to various roads. Most of the roads in Bexar and adjoining counties are named. The general position of the clay deposits is indicated on the accompanying index map (pl. 4), but its scale prevents the showing or naming of all the roads referred to. Persons interested in the detailed locations of the deposits may find the named roads on various county maps published locally or on the topographic sheets of the area published by the United States Army, the names and boundaries of which are shown on plate 4.

running on a reduced scale at the time of the writer's study. Some plants have also made low-grade pottery and heavy pottery, among them that now operating near Atascosa. Two plants near San Antonio are making glazed ornamental tile. No high-grade porcelain or china ware is being manufactured in the San Antonio area.

The following table gives information on clay plants now operating or operated in the near past in the San Antonio area:

Clay plants in San Antonio area

Name of firm	Location	Product	Source of clay	Status of plant
1. D'Hanis Brick & Tile Co.	D'Hanis, Medina County.	Brick and tile	Escondido formation, near plant.	Shut down.
2. Seco Pressed Brick Co.	do	Brick	Escondido formation, near plant.	Shut down?
3. Meyer Pottery Co.	Atascosa, Bexar County.	Flower pots, vases, dishes, jugs.	Upper part of Wilcox group near plant.	Operating.
4. Southern Co.	Quintana Road, San Antonio.	Sewer pipe, ornamental tile.	Brotze and Borrego pits in Wilcox group; Rosillo Creek pit in Midway group.	Operating.
5. San José Pottery Co.	Near San José Mission, south of San Antonio.	Ornamental tile	St. Hedwig and Borrego pits in Wilcox group.	Operating (opened in 1934)
6. Alamo Brick Co. (formerly Bem Brick Co.)	New Sulphur Springs Road, east part of San Antonio.	Brick	Midway group at plant.	Operating on reduced scale.
7. Star Products Co. (Saenger & Son, E. Richter.)	Elmendorf, Bexar County.	Brick, hollow tile, heavy pottery.	Upper part of Wilcox group near Borrego.	Abandoned about 1924.
8. San Antonio Sewer Pipe & Manufacturing Co.	Saspamco, Wilson County.	Sewer pipe	Upper part of Wilcox group near plant.	Shut down since 1930.
9. Mackey Brick & Tile Co.	Calaveras, Wilson County.	Brick	River silt	Abandoned, 1915
10. Suttles Pottery	Lavernia, Wilson County.	Brick, heavy pottery.	Reklaw (?) member south of Lavernia.	Abandoned, 1922
11. Blumberg Brick Works.	McQueeney, Guadalupe County.	Brick	Upper part of Navarro formation.	Shut down.
12. Sunset Brick & Tile Co.	Gonzales, Gonzales County.	Brick and tile	River silt	Shut down?

1. Liddle, R. A., The geology and mineral resources of Medina County: Texas Univ. Bull. 1860, pp 132–134, 1921.
2. Idem, pp. 134–136.
3. Ries, Heinrich, op. cit., p. 116; also information collected by writer.
4, 5. Information collected by writer.
6. Sellards, E. H., op. cit., p. 112; Ries, Heinrich, op. cit., pp. 171–172.
7. Sellards, E. H., op. cit., pp. 112–113; Ries, Heinrich, op. cit., p. 118; also information gathered by writer.
8. Sellards, E. H., op. cit., pp. 113–114; Ries, Heinrich, op. cit., p. 119; also information collected by writer.
9. Ries, Heinrich, op. cit., p. 200; also information collected by writer.
10. Ries, Heinrich, op. cit., pp. 120–121; also information collected by writer.
11. Some information from L. W. Stephenson; no other data.
12. Ries, Reinrich, op. cit., p. 203.

According to the Bureau of Mines,[62] Texas ranks ninth among the States in the value of clay products produced annually. Statistics on clay production in Texas have been given by Potter and McKnight.[63]

[62] Kiessling, O. E., Minerals Yearbook, 1934, pp. 876–877, U. S. Bur. Mines, 1934, Aug., figures to show present relative importance of clay industry in.

[63] Potter, A. D., and McKnight, David, op. cit. pp. 12–13.

DEPOSITS STUDIED

In a selection of the deposits of ceramic clay to be studied by the party, the writer was guided largely by the previous investigation of the San Antonio Chamber of Commerce. In that work "the principal method adopted to induce farmers and others to send or bring in samples of clays to the laboratory for testing was to enlist the aid by letter of 96 newspapers in 59 counties surrounding San Antonio." [64] By this method samples of nearly all the promising clay deposits in the area were probably obtained, and over 400 were examined by A. V. Lawton. From the samples examined by Mr. Lawton, the writer selected localities near San Antonio which were determined to have clay of good quality. The localities were tested by the Geological Survey party in order to determine the thickness and lateral extent of the good clays. Some additional localities worthy of study were also discovered by interviewing the local people. The writer also visited and sampled most of the important clay pits now being worked or those which had been worked in the past.

The present investigation revealed no deposits of clay of unusually high quality or of special properties. It did, however, yield information on the extent of clays suitable for the manufacture of brick, tile, and low-grade pottery. A summary of the properties and uses of the most interesting clays found is given in the table below.

Properties and uses of better clays of San Antonio area

Farm	Geological Survey test hole	University of Texas sample	Thickness of bed (feet)	Burned color	Recommendations
Padelecki (near St. Hedwig).	31	1, 2, 7	8	Cream	Brick, tile, pottery, low-grade firebrick.
	32	11	2		
Do	33	15, 16	5	Pink	Brick, tile, cheap pottery.
Do	34	17, 18	4	Brown gray	Dry-press bricks.
Cantu (near Sayers)	58	118	Surface.	Light buff	Common pottery.
Guy Edwards (near Sayers).	69	140–142	6	Gray	Brick, tile, pottery, semivitrified ware.
Weber (southeast of San Santonio).	35	28, 29	4	Light pink	Brick, tile, pottery, low-grade refractory ware.
Do	46	69–72	7	Buff	Dry press brick.
Vogt (near Von Ormy)	36	36–41	12	do	Cheap brick. (Too much lime).
Do	38	48	2	Light buff	As a mixture with other clays.
Do	39	52	2	Light red	Brick.
Do	44	62, 63	7	Near white	Low-grade refractory ware (too much flux).
Williams (near Thelma)	48	82–84	6	Light red	Brick or tile.
Salley (near Thelma)	49	94–96	6	Light pink	Possibly for semivitrified ware.
Miller (Atascosa County).	52	108–110	7	Buff to light red	Dry press brick and as a mixture with other clays.
	66	130–134	13		

TESTS OF CERAMIC CLAY SAMPLES

The clay samples collected by the party were examined in the laboratory of the Bureau of Industrial Chemistry, University of Texas,

[64] San Antonio Chamber of Commerce, op. cit., p. 6.

under the direction of David McKnight, Jr. A total of 140 samples were studied from southern Bexar and adjacent counties, 4 from McMullen County, and 6 from Morris County. The results of these tests are given at appropriate places in the report. All samples were entered under the laboratory serial number 528, and further distinguished by individual numbers following the general number.[65]

According to McKnight,

The clay samples received were first given a preliminary test as follows: The sample was examined in the raw state, and its color, hardness, plasticity, and state of purity were noted. The nature of the deposits near San Antonio is such that nearly all the samples are soft, of medium to high plasticity, and contain iron stains and occasional lime pebbles as impurities. Because of their uniformity, these observations are not included in the tables, and only the raw color is noted.

The sample was then ground, to aid in the tempering. Water was added gradually until the mass reached the best working consistency. The mass was then molded into bricklets 11.5 by 3 by 1.75 centimeters. The bricklets were air-dried to constant weight and then measured. The amount of drying shrinkage was calculated in terms of percentage of dry length. This is a very rough measurement, and is shown in the tables only to the nearest 0.5 percent.

The bricklets were then fired to cone 04. The firing was done in groups of five, so that all bricklets did not receive the same temperature treatment. However, the temperature attained for all was between 1,100 and 1,150° C., and the firing was stopped as soon as cone 04 came down. About 12 hours was used to bring the temperature up to 500° C., and about 6 hours to bring it from that point to the final temperature."

After cooling, the fired bricklets were examined. The measurement of length was made as before, and the firing shrinkage was expressed as percentage of dry volume. The color and condition of the fired bricklets were noted and are shown in the tables.

Those samples which showed promising properties in the preliminary tests were then subjected to more complete tests. Where a series of adjacent samples from one test hole gave indication of the presence of a bed of promising clay of workable thickness, these were combined in proportion to the thickness represented by each, and the complete tests made on the combined sample.

In the tables those samples on which complete tests were made are designated by an asterisk (*) after the laboratory number. Results of the complete tests are shown on the pages immediately following the tables of preliminary tests.

The complete tests included the following procedure: The sample was made up with that amount of water which had been found to produce the best consistency in the preliminary test. The tempered clay mass was formed into bricklets 2.5 by 2.5 by 4.5 centimeters, eight bricklets being made from each sample. These pieces were weighed and their volumes measured by submerging them in kerosene oil of known specific gravity.

The bricklets were dried first in air, and then in an oven maintained at 105° C., until their weights were constant. They were then weighed and soaked in kerosene. From these weighings the following data could be determined:

[65] Several sets of analyses are referred to in this report, each set with its own serial numbers, and in addition the localities studied by the present field party were distinguished by serial numbers. This will probably create some unavoidable confusion. In order to make the references as clear as possible, each serial number in the present paper is distinguished according to its source by the following initials: GS, localities and samples of the present U. S. Geological Survey field party; UT, samples studied by the Bureau of Industrial Chemistry, University of Texas; R, samples studied by Ries for the State of Texas; SA, samples studied by A V.. Lawton for the San Antonio Chamber of Commerce.

1. Pore water, or the amount of water removed in drying which is sufficient to fill the pores of the dry clay. Expressed in percentage of the dry weight.
2. Shrinkage water, or water removed during drying shrinkage. Determined by subtracting the pore water from the water of plasticity.
3. Water of plasticity, or total amount of water removed in drying. Expressed as percentage of dry weight.
4. Drying shrinkage. Determined by the loss in volume of the bricklet on drying. It should be noted that in the complete tests the volume, rather than the length, of the bricklets is measured, and the shrinkage is expressed as percentage of dry volume, and hence not in the same terms as employed in the preliminary tests. Volume shrinkage (*Sv*) can be calculated from linear shrinkage (*Sl*) by the following equation:

$$\frac{Sv}{100}=\left(\frac{Sl}{100}+1\right)^3-1$$

The bricklets were then fired, one bricklet from each sample being fired to each of a series of cones. The cones employed in this series of tests, and the temperatures observed when each cone came down are as follows:

	°C.		°C.
Cone 010	990	Cone 02	1, 110
Cone 08	1, 010	Cone 1	1, 140
Cone 06	1, 050	Cone 3	1, 170
Cone 04	1, 080	Cone 5	1, 210

After cooling, the volume and porosity of each bricklet were again measured. The shrinkage occurring on firing was calculated in terms of percentage of dry volume, and the porosity in percentage of fired volume. It should be noted that the fired shrinkage is thus recorded in the same terms as the dry shrinkage, but that the porosity of the fired bricklet is based on the fired volume, and the figure recorded indicates the proportion of external volume of the fired piece which is occupied by pore space.

The color and condition of the fired pieces at each of the temperatures to which the various pieces were fired were also noted and are recorded in the tabulation of complete tests.

In addition to the tests made by the Bureau of Industrial Chemistry on samples collected by the Geological Survey party, the results of tests made by some other investigators are included in this report, notably those of Lawton and Ries. Their results are valuable, but their procedure was not always the same as that of the Bureau of Industrial Chemistry, and some of their results are expressed in a different manner. It was not possible to recalculate their results so as to make them comparable with those obtained during the present investigation.

CLAYS IN CRETACEOUS ROCKS

Only the upper part of the Cretaceous rocks, the Taylor and Navarro formations, are clay-bearing in the vicinity of San Antonio and in these the clay is likely to be calcareous, a quality which renders them unfavorable for use. Clay has, however, been worked at two places.

Northeast of San Antonio, 1 mile south of McQueeney, in Guadalupe County, is the pit of the Blumberg Brick Works, which according to L. W. Stephenson is in the upper part of the Navarro formation. This was not studied by the writer, and no information on it is available.

West of San Antonio, at D'Hanis, in Medina County, are the pits of two companies. Their geologic character and the methods of operation have been described by Liddle,[66] and the results of physical and chemical tests on the clay by Ries.[67] According to Stephenson the pits lie in the Escondido formation, which is the western equivalent of a part of the Navarro formation. They were not studied by the writer.

Apparently no clay is being produced from rocks of Cretaceous age within Bexar County itself.

CLAYS IN THE MIDWAY GROUP

General character of the group.—The Midway group, or lowest stratigraphic unit in the Eocene series of the Texas Gulf Coastal Plain, crops out in an irregular belt, much broken by faults, which extends southwestward across central Bexar County. The upper part of the group, or Wills Point formation, contains several clay deposits that have been worked near San Antonio. According to Plummer [68] this upper formation, about 250 feet in thickness, consists of "a little glauconite or glauconitic clay at the base, above which is compact fossiliferous clay, grading up into sparsely fossiliferous layers of silty clay at the top." The workable beds apparently lie in the lower clay member of the formation.

Alamo Brick Co.'s clay pit.—The pit of the Alamo Brick Co. (successor to the Bem Brick Co.) lies near its clay plant north of the New Sulphur Springs Road, just east of the city limits of San Antonio, in the East San Antonio quadrangle. (See pl. 4.) It has been described by C. L. Baker.[69]

According to Baker the clay is dark blue gray, carrying much fibrous and platy selenite and weathering light yellowish and drab. It contains large brown cone-in-cone concretions, small nodules of limonite, and some marine fossils. According to Ries [70] the clay has a high plasticity, slow slaking power, and contains 0.92 percent of soluble salts.

> It has little grit, but very high plasticity and great stickiness. * * * The clay has to be dried very slowly to prevent air cracking, and it was difficult to get briquets that were free from flaws * * * When burned wet-mud it swells, cracks, and blisters so that in order to produce a salable product it has

[66] Liddle, R. A., op. cit., pp. 132-136. See also Sayre, A. N., geology and ground-water resources of Uvalde and Medina Counties, Tex.: U. S. Geol. Survey Water Supply Paper 678 p. 58, 1936.

[67] Ries, Heinrich, op. cit., pp. 197-198.

[68] Plummer, F. B., op. cit., p. 562.

[69] Quoted by Sellards, E. H., op. cit., p. 112.

[70] Ries, Heinrich, op. cit., pp. 170-172.

to be worked by the dry-press process. * * * The burned bricklets contained many small white specks which are due to the gypsum particles which the clay contained and are not due to carbonate of lime.

The following tests were made by Ries (sample R 811):

Water of plasticity	29. 7	Cone 1:	
Air shrinkage	9. 3	Shrinkage	3. 3
Average tensile strength	169	Absorption	4. 1
Cone 05:		Color	dark brown
Shrinkage	3. 3	Cone 3:	
Absorption	10. 6	Shrinkage	5. 7
Color	light brown	Absorption	2. 1
Cone 03:		Color	dark red brown
Shrinkage	3. 3	Viscous at cone 5.	
Absorption	10. 7		
Color	red brown		

The chemical composition, as determined for Ries by O. H. Palm and S. H. Worrell, is as follows:

SiO_2	59. 47	CO_2	3. 23
Al_2O_3	18. 24	H_2O	5. 70
Fe_2O_3	4. 77	SO_3	. 90
CaO	4. 30	Organic matter	. 55
MgO	trace		
Na_2O	. 24	Total	98. 54
TiO_2	1. 14		

Old clay pits on Salado Creek.—Southeast of San Antonio, about a quarter of a mile south of the Upson Road, on both slopes of a small valley draining eastward into Salado Creek, in the East San Antonio quadrangle (pl. 4), are the remains of some old brickyards whose clay was obtained from exposures of the Midway nearby.[71] On the west side of the valley are the remains of kilns which are reported to have been operated at the time of the construction of the Spanish missions (see p. 97). On the east side of the valley are the remains of a more recent brickyard, operated by a Mr. Olsen from the 1870's to the 1890's.

The following sequence of strata was observed in descending order on the west side of the valley. The thicknesses given are approximate.

Section on west side of Salado Creek

	Feet
5. Loess, with snail shells and some pebbles	20
4. Clay, dark gray to black, waxy, with conchoidal fracture; iron nodules, some selenite; marked by yellow streaks	20
3. Shale, light gray	5
2. Sandstone, buff, calcareous, with thin bedding planes; some selenite; cropping out in massive ledges	(?)
1. Clay, sandy, containing calcareous sandstone concretions 1 foot thick and 2 to 5 feet across; Crops out in channel just above point where valley joins Salado Creek	(?)

[71] The writer was guided to this locality by H. B. Parks.

The old clay pits, which nowhere appear to have been carried far below the surface, are mostly in member 4 of the section. The clay appears to be like that in the Alamo Brick Co.'s pit, and like it burns red.

Clay pit on Rosillo Creek.—East of San Antonio on the east bank of Rosillo Creek, near the crossing of the Gonzales Road, in the East San Antonio quadrangle (pl. 4), similar clays of the upper part of the Midway group are being dug. They are used by the Southern Co. at its tile plant in the southwestern part of San Antonio.

Clay on Fike places.—About 2¼ miles southwest of the southwest corner of the city of San Antonio, on the southeast side of the Quintana Road, opposite the Humble Refinery, in the West San Antonio quadrangle, are the G. W. and W. P. Fike places (pl. 4). The locality was not examined by the writer, but some clays of good quality seem to be present. Two samples examined by A. V. Lawton (SA 47 and 219) were classed by him as brick and tile clay of best quality. One other (SA 173) was classed as a brick clay, but he states that it could be used only in a mixture with other clays. Five samples (SA 216, 217, 218, 220, 256) were rejected because they contained too much lime. The deposit apparently lies in the Midway group, and one of the samples examined by Lawton is classed as a greensand.

CLAYS IN THE WILCOX GROUP

General character of the group.—Most of the important ceramic clay deposits in the San Antonio area lie in the Wilcox group and belong to the Indio formation. This group lies unconformably on the Midway group and has a thickness of about 500 feet.[72] It crops out over a wide area in the southern part of Bexar County (pl. 4).

The greater part of the Wilcox deposits are of nonmarine origin and consist of gray, brown, and reddish sands, sandy clays, and clays. In many places the sands have been indurated by cementation into large boulderlike concretionary masses. In places the remains of fossil plants are abundant, and here and there carbonaceous seams and thin beds of lignite may be seen. Clays of commercial quality occur in beds from a few feet to more than 10 feet in thickness, but most of them are lenticular and lose their thickness rapidly along the strike. Many test holes were put down by the Geological Survey party to determine the extent of such lenticular deposits. The nonmarine beds give rise to a reddish soil that covers most of the surface, but along streams the beds are characteristically eroded into small badlands in which the Wilcox clays and sands are well exposed. This dissection has in places made it possible to dig out small quantities of clay for ceramic use without the necessity of stripping off the overburden.

[72] Plummer, F. B., op. cit., pp. 574, 585. For notes on outcrops in Bexar County, see Parks, H. B., and Kirn, A. J., op. cit., pp. 11–16.

At the top and base of the Wilcox group in parts of central Texas are thin beds of marine origin.[72a] On this basis Plummer has divided the Wilcox into three formations, calling the lower marine beds the Seguin, the middle nonmarine beds the Rockdale, and the upper marine beds the Sabinetown. In the San Antonio area, however, the marine beds do not seem to have a very constant development. The lower one was not recognized by the writer, although H. B. Parks reports that he has recently found several localities for its fossils in Bexar County.

The upper marine beds are well exposed at several places in the southeastern part of Bexar County, as near the crossings of Calaveras and Chupaderas Creeks by the Adkins-Elmendorf road, and the crossing of Parita Creek by the Stuart Road. They are also found at the crossing of the South Flores Road over Losoya Creek, half a mile south of the village of Losoya.[73] At these places the marine beds consist of a thin conglomerate of rounded pebbles containing embedded marine shells resting on a massive ledge of cross-bedded and ripple-marked sandstone. Above are dark-gray, brown, and black clays, thinly laminated by seams of sand and carbonaceous matter, which reach an exposed thickness of about 25 feet. Their character is similar in all exposures. In places they have been used for brick clay.

At many places the upper marine beds are not present. Thus at the clay pits at Borrego, 4 miles south of Elmendorf, in the southeastern part of the county, ledges of massive, coarse-grained Carrizo sand rest directly on sands and clays that seem to be of nonmarine origin. Whether the marine beds are discontinuous because they were originally lenticular, channel-like deposits, or whether they were once more extensive and were afterwards partly removed by pre-Carrizo erosion cannot be stated at this time.

St. Hedwig deposit.—About 1½ miles east-southeast of the church at St. Hedwig, on the Padelecki farm,[74] in the Lavernia quadrangle (pl. 4), there are low exposures of white clay for several hundred feet along Lupon Creek north of the farm house. These probably belong to the lower part of the Wilcox group. The surrounding country is gently rolling and is covered by a red sandy soil, so that few other exposures are to be found. Some of the hilltops north of the creek are capped by Quaternary gravel. Some clay was taken out here about 10 years ago, and recently several truck loads have been dug and used by the San Jose Pottery, south of San Antonio. No large pits have been opened up.

[72a] Gardner, J. A., Fossiliferous marine Wilcox in Texas: Am. Jour. Sci., 5th ser., vol. 7, pp. 141-145, 1924.

[73] The writer was guided to these localities by H. B. Parks, who has also published brief notes on them. See Parks, H. B., and Kirn, A. J., op. cit., p. 16. The Losoya locality is described by Sellards, E. H., op. cit., pp. 58-59, 69; Deussen, Alexander, op. cit., pp. 55-56 and pl. 18, *B;* and Plummer, F. B., op. cit., pp. 603-604.

[74] Shown as the Gedaski farm on the Lavernia map by the U. S. Army.

Four test holes were put down by the Geological Survey party to determine the extent of the deposit—one at the exposures on the creek where the clay is now being dug (GS 31),[75] and the others 500 feet south-southwest (GS 32), 300 feet north-northwest (GS 33), and 325 feet west-northwest (GS 34) (fig. 9). At the locality along the creek 4 feet of clay is exposed in the creek bank and in the pit below, and 4 feet more is penetrated in the test hole below the base of the pit. Above the clay on the creek bank is an overburden of buff argillaceous sand 7 feet thick. Below the clay bed are coarsely sandy iron-stained clays and varicolored sands, whose contact with the clay is gradational.

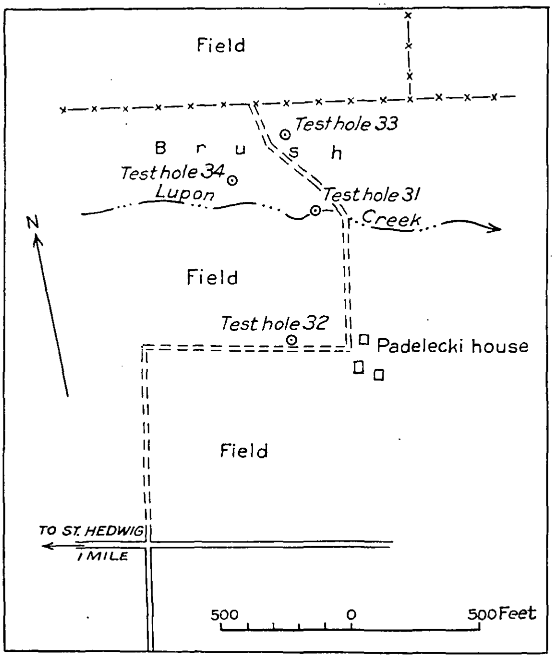


FIGURE 9.—Map of Padelecki farm, Bexar County, Tex.

The same clay bed is recognizable in the other test holes at about the same altitude, for the strata appear to lie nearly horizontal. The exposures along the creek apparently lie near the thickest part of the deposit, for in hole GS 32, to the south-southwest, the bed is only 4 feet thick, in hole GS 33, to the north-northwest, 3 feet, and in hole GS 34, to the west-northwest, 4½ feet. The horizontal attitude of the beds and the rise of the ground away from the creek cause the overburden to thicken considerably away from the first locality. In test hole GS 32 the clay bed is overlain by 17 feet of sand.

The clay samples were tested by the Bureau of Industrial Chemistry, and the preliminary and complete tests are shown on the following

[75] These numbers were used in the field to designate the test holes and sample localities. The test holes in the San Antonio area are shown by number on plate 4, and figures 9 to 14.

pages. Complete tests of the main clay bed were made on samples UT 1 and UT 2 combined, on sample UT 7, and on sample UT 11. According to McKnight,

All these burn to light cream and near white and attain a good hard body at low temperatures. The very slight increase in shrinkage and decrease in porosity with increasing temperatures suggests the possibility of refractory properties. A chemical analysis of the combined sample UT 1–2 shows that no very high degree of refractoriness may be expected, although the percent of fluxes is probably not too high to expect that a low-grade fire brick could be made from the clay. The clay would make good brick, tile, or pottery, although the evidence of the test holes does not prove that there is enough of the clay available to justify the location of a plant there.

The clays in test holes GS 33 and GS 34 show different properties on testing. Two samples from hole GS 33 (UT 15 and 16), covering the interval of 9 to 14 feet, represent a bed of orange-gray clay that burns to a light pink and at higher temperatures to a buff body of good character. It should make brick, tile, and cheap pottery. The clay in hole GS 34 between depths of 6 and 10 feet (UT 17 and 18) is brownish gray and burns to a good hard body. The high dry shrinkage of the clay would make it troublesome to work in the plastic state, but it would probably make good dry-press bricks.

The following tables show the detailed results of tests made by the Bureau of Industrial Chemistry:

Tests of clay on Padelecki farm

Preliminary tests

Depth in test hole (feet)	Raw color	Shrinkage (percent)		Fired color	Fired condition	UT laboratory No.
		Drying	Firing			
GS 31						
1-2	Light gray	4	0.5	Near white	Good	1
2-4	Gray	4	.5	Very pale pink	do	2
4-6	do	4.5	−1.5	do	do	3
6-8	do	5.5	−1.0	Pink	Fair	4
8-10	do	4.0	.0	Pale pink	Poor	5
10-12	do	5.5	.0	Pink	do	6
Composite of 4 feet above mouth of hole.	Light gray			Dirty white	Good	7
GS 32						
6-8	Brownish gray	15	2	Buff	do	8
8-10	do	14	1	do	do	9
10-17	(Sand, not tested.)					
17-19	Light gray	7.5	.0	Light pink	Fair	10
19-21	do	7.5	.5	Dirty white	do	11
21-23	do	9.5	1.0	Cream	Good	12
23-25	do	11.5	1.5	do	do	13
25-27	Orange gray	11.5	.5	Light red	do	14
GS 33						
9-11	do	5	1.5	do	do	15
11-14	do	4.5	.0	do	Fair	16
GS 34						
6-8	Brownish gray	8.5	1.0	Buff	Good	17
8-10	do	9.0	1.0	do	do	18
11-12	Grayish orange	8.5	.0	Medium-red	do	19

Tests of clay on Padelecki farm—Continued

Complete tests

[See p. 100]

	UT 1, 2	UT 7	UT 11	UT 15, 16	UT 17, 18
Dry color	Light gray	Light gray	Light gray	Orange gray	Brown gray.
Hardness	Soft	Soft	Soft	Soft	Medium.
Shrinkage water	3.8	8.6	5.0	3.4	11.7.
Pore water	12.7	12.8	11.7	11.9	9.9.
Water of plasticity	16.5	21.4	16.7	15.3	21.6.
Dry shrinkage	9.7	17.5	11.5	8.7	22.5.
Cone 010:					
Color	Light cream	Near white	Light cream	Pink	Cream.
Condition	Hard	Hard	Very hard	Very hard	Very hard.
Shrinkage	0.3	1.7	0.0	0.2	0.8.
Porosity	28.4	28.9	26.8	29.1	24.8.
Cone 08:					
Color	Light cream	Near white	Light cream	Pink	Cream.
Condition	Hard	Hard	Very hard	Very hard	Very hard.
Shrinkage	1.5	2.1	0.6	0.2	0.3.
Porosity	29.7	29.9	27.2	30.0	22.3.
Cone 06:					
Color	Light cream	Near white	Light cream	Light pink	Buff.
Condition	Hard	Hard	Very hard	Very hard	Steel hard.
Shrinkage	1.7	2.5	2.1	0.4	2.0.
Porosity	29.5	28.7	27.0	29.5	20.8.
Cone 04:					
Color	Light cream	Near white	Dirty white	Light pink	Buff.
Condition	Hard	Hard	Very hard	Very hard	Steel hard.
Shrinkage	1.5	2.2	1.7	1.1	1.7.
Porosity	29.6	29.2	26.9	29.8	19.9.
Cone 02:					
Color	Light cream	Near white	Dirty white	Light pink	Buff.
Condition	Hard	Hard	Very hard	Very hard	Steel hard.
Shrinkage	3.8	6.5	3.7	3.1	4.0.
Porosity	27.2	25.6	24.4	27.4	19.9.
Cone 1:					
Color	Near white	Near white	Dirty white	Buff	Buff.
Condition	Very hard	Steel hard	Very hard	Very hard	Steel hard.
Shrinkage	6.5	4.7	5.5	4.2	2.9.
Porosity	24.4	20.6	21.9	26.2	18.6.
Cone 3:					
Color	Near white	Near white	Dirty white	Buff	Buff.
Condition	Very hard	Steel hard	Very hard	Very hard	Steel hard.
Shrinkage	5.4	12.0	3.7	3.5	5.2.
Porosity	24.5	20.3	24.2	27.5	20.4.
Cone 5:					
Color	Near white	Near white	Dirty white	Buff	Buff.
Condition	Very hard	Steel hard	Very hard	Very hard	Steel hard.
Shrinkage	6.6	8.8	5.9		5.0.
Porosity	23.9	21.8	21.3	26.5	19.7.

The following is a chemical analysis of the combined samples UT 1 and 2:

	Percent		*Percent*
SiO_2	72. 40	Na_2O and K_2O	2. 51
Al_2O_3	14. 75	TiO_2	. 95
Fe_2O_3	1. 62	CO_2 and H_2O	5. 24
CaO	1. 79		
MgO	. 0	Total	99. 26

Other workable clay beds may exist in the same neighborhood. A sample obtained 1½ miles north of St. Hedwig, submitted by Otto Brotze to the San Antonio Chamber of Commerce, was reported by A. V. Lawton to be a clay suitable for brick, tile, or pottery (SA 239).

Deposits near Sayers.—About 1½ miles east of the village of Sayers, north and south of the Gonzales Road, clays of various types are exposed on tributaries draining southwest into Chupaderas Creek;

in the East San Antonio quadrangle (pl. 4). These are found on the farms of E. M. Edwards, Guy Edwards, Matthew Cantu estate,[76] and Mrs. T. E. Trainer (fig. 10). The strata probably belong to the lower part of the Wilcox group.

The E. M. Edwards 125-acre tract, which lies north of the Gonzales Road and west of the Mount Olive Road, has few surface exposures. Some clays have been uncovered in digging a water tank in the northern part of the tract, and a hole put down there by the Geological Survey party (GS 65) showed gray sands, in part argillaceous, to a depth of 11 feet. According to Mr. McKnight, the samples from this test hole are similar to those collected from the surface on the Cantu farm, described below. "However, the unweathered samples obtained from this hole are less plastic than the surface samples and do not attain nearly the hardness on firing that the surface samples do. These samples show no promise whatever." The following preliminary tests have been made by the Bureau of Industrial Chemistry:

Depth (feet)	Raw color	Shrinkage (percent)		Fired color	Fired condition	UT laboratory no.
		Drying	Firing			
1-5	Gray	1.0	0.0	Pink	Poor (sandy)	125
5-7	do	.0	−1.5	do	do	126
7-9	do	2.5	−1.0	Dirty white	Poor	127
9-11	do	2.0	−1.0	Light red	do	128

The Guy Edwards tract is southwest of the E. M. Edwards tract, on the south side of the Gonzales Road. A hole drilled here by the Geological Survey party (GS 69) just west of the boundary line of the Cantu tract showed gray sands, in part argillaceous, to a depth of 11 feet. According to McKnight, the clay obtained in this hole is somewhat different from that on the E. M. Edwards and Cantu farms.

The orange and purple colors found in the raw clay are distinctive, as is also the absence of gritty texture of the material as a whole, although a good deal of sand is present. The three samples (UT 140–142) covering the interval from 2 to 8 feet were combined for complete tests and for chemical analysis. The chemical analysis reveals too much iron and alkalies for refractory purposes. The bricklets formed from the combined samples burn to a very pleasing gray at cone 02, forming a very hard body at the same point. The clay would probably make good brick, tile, or pottery if fired at cone 02 and above. There is also promise of semivitrified ware or low grade stoneware if fired above cone 5. The data furnished by this one test hole are not sufficient to determine the commercial value of the bed.

The following preliminary tests were made on the samples by the Bureau of Industrial Chemistry. The complete test and the chemical analysis are given on pape 113, under the description of the Cantu estate.

[76] Shown as "Canton" on the East San Antonio map by the U. S. Army.

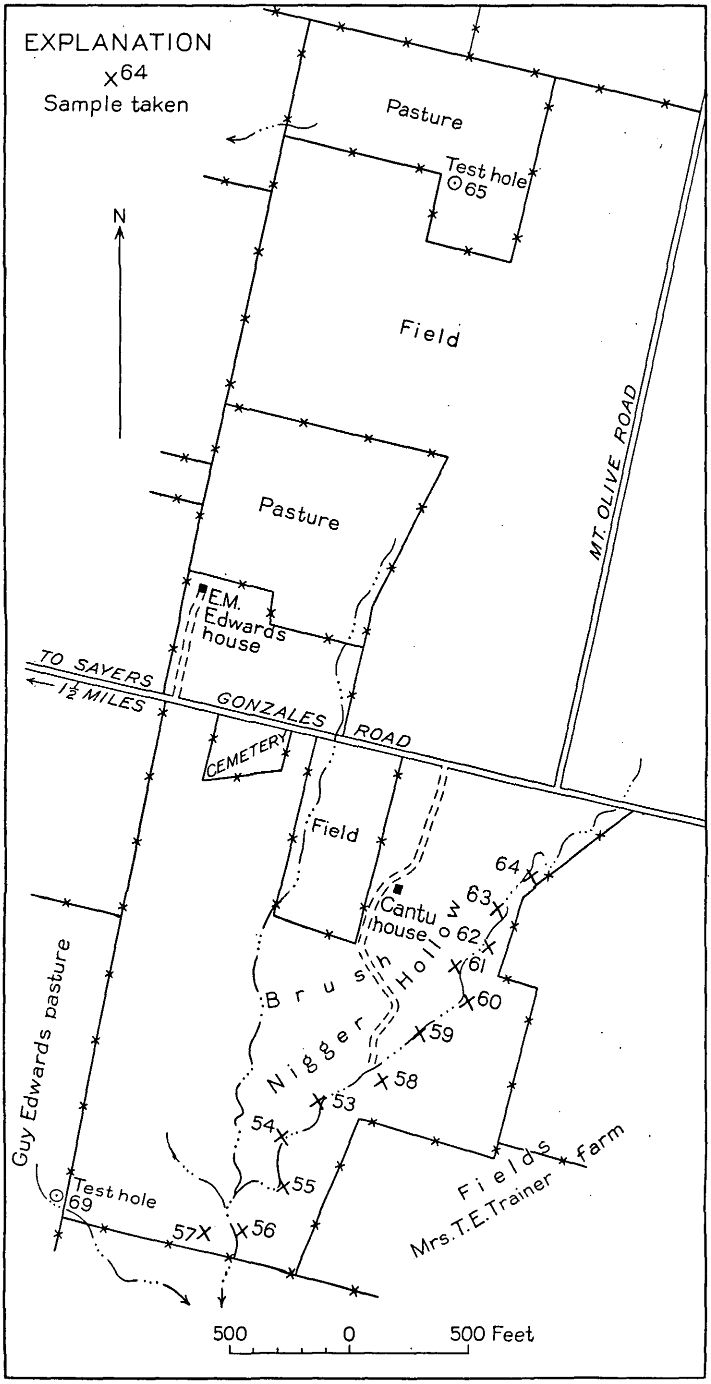


FIGURE 10.—Map of the Cantu and Edwards farms, Bexar County, Tex., showing location of test holes.

Depth (feet)	Raw color	Shrinkage (percent)		Fired color	Fired condition	UT laboratory no.
		Drying	Firing			
0-2	Gray and orange	4.5	0.0	Red	Good	139
2-4	Light gray	4.5	2.0	Near white	Very good	140
4-6	do	4.5	1.0	Pink	do	141
6-8	Purplish	3.5	1.0	Light purple	Good	142
8-9	do	3.5	1.0	Dark purple	do	143
9-11	Orange	4.5	1.5	Red	do	144

The best exposures in the neighborhood are on the tract of the Matthew Cantu estate, which lies east of the Guy Edwards place and south of the E. M. Edwards place. Beginning just south of the Gonzales Road, a ravine and its tributaries known locally as Nigger Hollow has cut into the bedrock and exposed white sandy clays and argillaceous sands for a distance of about half a mile south of the road. The dip of the strata is at a low angle southward down the ravine, but varies from exposure to exposure. Part of the strata consist of flourlike sandy clays, which show an efflorescence of mineral salts on the surface. There appears to be considerable lateral change in the deposit, however, and the observations of H. C. Fountain suggest that the clays change into more sandy strata in an upstream direction. The deposit appears to be underlain by red sand and to be overlain by lignitic clays with ellipsoidal sandstone concretions.

A large quantity of clay has been dug along these ravines. In 1903, at the time of Ries' visit, the clay was being shipped to Gonzales, Houston, and New Orleans.[77] That sent to Gonzales was used by the Sunset Brick & Tile Co. "for making a so-called fire brick for the construction of kiln arches." [78] In recent years most of the clay has been sold to the Alamo Iron Works, in San Antonio. It is reported that it is used by that concern for refractory purposes, and that it is packed directly into the cupolas of the furnaces. It is said to withstand a temperature of as much as 2,800° F.[79]

Twelve samples were collected from the surface at various points along the main ravines (localities GS 53–64). According to McKnight,

> The material resembles volcanic ash in texture but shows a surprising plasticity for such gritty matter. It is iron-stained in crevices, and this impurity shows up in all the samples in the pink, buff, and yellow colors produced on firing. The lightest color produced was that of the sample from locality GS 58 (UT 118), which also was probably the most plastic of the twelve submitted. This sample was selected for complete test. In the complete test it burned to a very light buff, with a very hard body, becoming steel hard at cone 1. It would probably make good common pottery if there were enough of it to work. The extremely variable nature of the clay beds exposed makes it doubtful if the deposit could be worked.

77 Ries, Heinrich, op. cit., p. 86.

78 Idem, p. 156.

79 Information from J. R. Martin, of San Antonio.

Two samples from the Cantu deposit were studied by Ries,[80] and their somewhat different characters illustrate the variability of the deposit. One (R 815) is a brown sandy, fairly plastic clay of moderate refractoriness which could be used for No. 2 fire brick or for wet-mud common brick. It burns buff or gray. The other (R 926) is a white clay of fairly high refractoriness.

The following tests were made by the Bureau of Industrial Chemistry on samples collected by the Geological Survey party:

Tests of clays from Cantu and Edwards farms

Preliminary tests (Cantu farm)

GS. locality no.	Raw color	Shrinkage (percent)		Fired color	Fired condition	UT labora-tory no.
		Drying	Firing			
53	Gray	2.0	0.0	Dirty yellow	Poor	113
54	do	2.5	.0	Near white	do	114
55	do	3.5	3.5	Pink	Very good	115
56	Light gray	2.5	2.0	do	Good	116
57	Gray	3.5	2.5	do	do	117
58	Light gray	4.5	1.0	Near white	Very good	118
59	do	3.5	2.0	Dirty yellow	do	119
60	do	4.0	.5	Near white	Fair	120
61	do	3.0	.0	do	Poor	121
62	Red and gray	4.0	3.0	Buff	Good	122
63	Light gray	3.5	.0	Pink	Fair	123
64	do	4.5	2.0	Dirty yellow	Good	124

53. Cut in west bank of Nigger Hollow, 225 feet below road from house.
54. Cut in west bank, 170 feet below locality 53.
55. Cut in east bank, 200 feet below locality 54.
56. Cut in east bank, 275 feet below locality 54.
57. Cut in west bank, 200 feet below locality 56.
58. Cut opposite road from house.
59. Cut in west bank, 250 feet above locality 58.
60. Cut in east bank, 225 feet above locality 59.
61. Cut in west bank, 150 feet above locality 60.
62. Cut in east bank, 125 feet above locality 61.
63. Cut in west bank, 210 feet above locality 62.
64. Cut in east bank at upper end of exposure.

Complete tests (Cantu and Guy Edwards farms)

	UT 118	UT 140–142
Dry color	Light gray	Light gray.
Hardness	Soft	Soft.
Plasticity	High	High.
Shrinkage water	4.1	5.8.
Pore water	13.7	13.8.
Water of plasticity	17.8	19.6.
Drying shrinkage	9.2	13.6.
Cone 010:		
Color	Light buff	Flesh.
Condition	Very hard	Hard.
Shrinkage	−1.0	−0.7.
Porosity	33.9	31.0.
Cone 08:		
Color	Light buff	Flesh.
Condition	Very hard	Hard.
Shrinkage	0.4	0.4.
Porosity	34.4	31.6.
Cone 06:		
Color	Light buff	Flesh.
Condition	Very hard	Hard.
Shrinkage	0.9	2.1.
Porosity	34.3	31.1.

[80] Ries, Heinrich, op. cit., pp. 84–86, 155–157.

Tests of clays from Cantu and Edwards farms—Continued

Complete tests (Cantu and Guy Edwards farms)—Continued

	UT 118	UT 140–142
Cone 04:		
Color	Light buff	Flesh.
Condition	Very hard	Hard.
Shrinkage	1.8	1.6.
Porosity	34.3	31.2.
Cone 02:		
Color	Light buff	Very light gray.
Condition	Very hard	Very hard.
Shrinkage	4.7	4.2.
Porosity	32.3	29.3.
Cone 1:		
Color	Light buff	Very lignt gray.
Condition	Steel hard	Very hard.
Shrinkage	7.4	7.8.
Porosity	29.7	26.0.
Cone 3:		
Color	Light buff	Very light gray.
Condition	Steel hard	Very hard.
Shrinkage	6.3	8.5.
Porosity	30.6	26.6.
Cone 5:		
Color	Light buff	Gray.
Condition	Steel hard	Steel hard.
Shrinkage	7.6	9.1.
Porosity	29.3	24.1.

The following table gives a chemical analysis made by the Bureau of Industrial Chemistry on the combined sample UT 140–142, from the Guy Edwards property. To this have been added the chemical analyses made for Ries of the two samples studied by him from the Cantu property (R 926 and R 815).

	UT 140–142	R 926	R 815
SiO_2	66.77	69.70	68.70
Al_2O_3	16.27	21.50	15.90
Fe_2O_3	3.25	.40	3.30
CaO	.47	Trace	3.10
MgO	.85	.50	.50
Na_2O	1.97	1.00	.30
K_2O	.91	.30	Trace
TiO_2	1.78	.12	1.40
CO_2+H_2O	7.33		
H_2O		7.10	5.90
Total	100.60	100.62	99.10

Mrs. T. E. Trainer's farm, southeast of the Cantu farm, is apparently underlain by material very similar to that on the Cantu farm. One sample examined by Lawton (SA 228), was classed by him as a refractory clay of best quality, but another (SA 126) was rejected because of its high content of sand.

Weber deposit.—The F. H. Weber place lies 6¾ miles southeast of the southeast corner of the city of San Antonio and a quarter of a mile west of the Foster Road, between the Hildebrand and Cassiano Roads, in the East San Antonio quadrangle (pl. 4). It is drained by several southeastward-flowing tributaries of Calaveras Creek, along which are exposures of sands and clays, probably of the lower part of the Wilcox group.

The best exposures are near a tank 100 yards southwest of the farmhouse (fig. 11), where ravines show outcrops a few feet in height of white flourlike sandy clays and purer gray clays. A test hole (GS 35) west of and upstream from the tank showed white, finely sandy clays, with some iron stains and seams of sand, to a depth of 13 feet, below which were gray and yellow sands with some clay seams. East of the tank and at a lower altitude a test hole was put down to a depth of 10 feet (GS 45), which probably showed beds at a lower stratigraphic position. These consist largely of sandy clays, with some seams of sand and purer clays, grading down into argillaceous sand. A pit

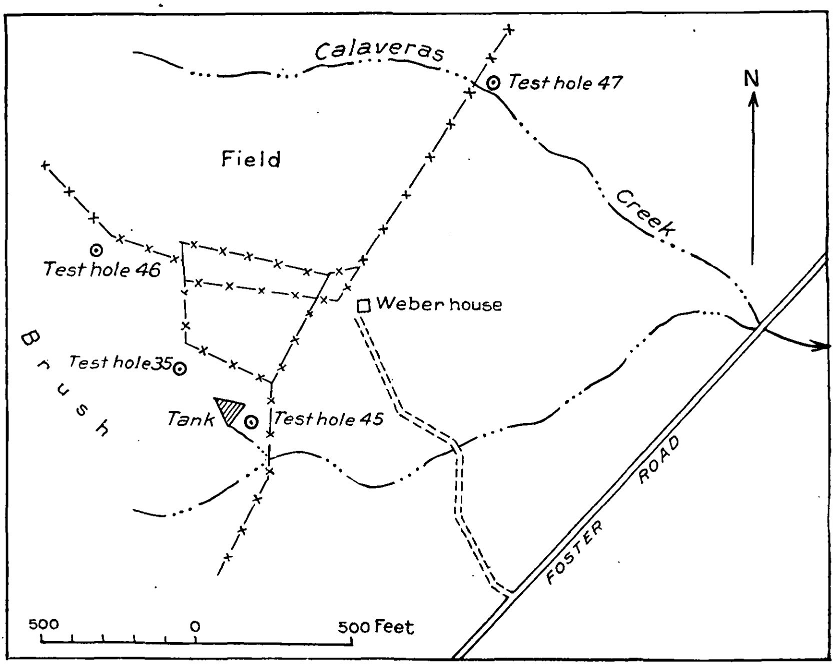


FIGURE 11.—Map of Weber farm, Bexar County, Tex., showing location of test holes.

sunk nearby to a depth of 12 feet under the direction of A. V. Lawton, at the time of the San Antonio Chamber of Commerce investigation, showed similar material, with the layers of relatively pure clay not reaching a thickness of more than 2 feet.

Beds overlying the deposit are exposed on a low rounded hill about a quarter of a mile west of the farmhouse. Here there are one or two thin beds of sandy ferruginous material which have been broken up by weathering into small fragments rich in limonite and hematite. These strew the surface in great numbers. Several pits that have been dug in the hillside show that the greater part of the material is fine gray sand and gray sandy clay. Similar material was found in a test hole (GS 46) 7 feet deep put down by the Geological Survey party.

North of the farmhouse along a shallow ravine are low exposures of white flourlike argillaceous sand, interbedded with thin beds of blue-gray clay of greasy feel and possibly bentonitic character. A test hole (GS 47) put down here to a depth of 7 feet by the Geological Survey party showed similar material, with some interbedded layers of red sand.

According to McKnight,

The four test holes on this property reveal few samples of any interest. Most of the samples obtained yield a very poor fired body. A dark-gray clay found between 9 and 13 feet (UT 28, 29) at locality 35 yielded a good pink body, and the two samples representing this interval were combined for complete tests. This combined sample burned to light colors and good strong bodies at all temperatures employed. The clay would probably make good brick, tile, or common pottery if fired between cones 1 and 5. A chemical analysis on the combined samples shows a fairly low proportion of fluxing constituents, too high to promise high refractory properties but probably low enough to indicate the possibility for low-grade refractory ware.

The dark-gray clay found in all 7 feet of the depth of the test hole at locality GS 46 burns buff and gives a good body. The four samples from this hole were combined for complete tests and found to show favorable characteristics. The clay would make common brick, best fired above cone 1. Because of the somewhat high drying shrinkage the clay might best be worked by the dry-press method, although no trouble was encountered in drying the laboratory specimens. Again a definite opinion as to the commercial value of the deposit is impossible in the absence of data as to the extent of the deposit.

The following tests were made by the Bureau of Industrial Chemistry on clays collected by the Geological Survey party from the Weber farm:

Tests of clays from F. H. Weber farm

Preliminary tests

Depth (feet)	Raw color	Shrinkage (percent)		Fired color	Fired condition	UT laboratory no.
		Drying	Firing			
GS 35						
3–5	Gray and red	4.5	1.0	Pink	Fair	24
5–6	Light gray and orange	4.5	.5	Very light red	do	25
6–8	do	4.5	.5	Pink	do	26
8–9	do	2.5	.0	Very light red	Poor	27
9–11	do	4.5	.0	Pink	Good	28
11–13	Darker gray	4.0	.5	Near white	do	29
13–15	Light gray	3.5	.0	Pink	Fair	64
15–17	do	3.5	.0	Very light red	do	65
GS 45						
4–6	Gray	4.5	.0	Pink	do	66
6–8	do	3.5	.0	do	do	67
8–10	Gray and red	3.5	−.5	Darker pink	do	68
GS 46						
1–2	Dark gray	6.5	2.0	Light buff	Good	69
2–3	Gray	7.5	2.0	Buff	do	70
3–5	do	6.5	.5	do	Fair	71
5–7	Light gray	7.5	1.0	do	Good	72
GS 47						
Surface	Red	3.5	−.5	Red	Poor (sandy)	73
2½–3½	Light gray	9.0	4.5	Buff	Good	74
4–6	Brown	4.0	−.5	Red	Poor	75
6–8	Gray	5.5	.5	Light red	Fair	76
8–9	Dark gray	9.5	3.0	do	Good	77

Tests of clays from F. H. Weber farm—Continued

Complete tests

	UT 28, 29	UT 69, 70, 71, 72
Dry color	Light gray	Gray.
Hardness	Soft	Soft.
Plasticity		Medium.
Shrinkage water	7.9	10.6.
Pore water	12.9	10.7.
Water of plasticity	20.8	21.3.
Dry shrinkage	14.1	21.4.
Cone 010:		
Color	Light flesh	Buff.
Condition	Very hard	Hard.
Shrinkage	2.2	0.9.
Porosity	28.6	24.2.
Cone 08:		
Color	Light flesh	Pinkish buff.
Condition	Very hard	Hard.
Shrinkage	−1.1	−1.2.
Porosity	29.2	23.8.
Cone 06:		
Color	Light cream	Buff.
Condition	Very hard	Hard.
Shrinkage	−0.3	0.8.
Porosity	24.6	22.9.
Cone 04:		
Color	Light cream	Buff.
Condition	Very hard	Very hard.
Shrinkage	−0.6	0.9.
Porosity	29.1	21.5.
Cone 02:		
Color	Light yellow	Buff.
Condition	Very hard	Very hard.
Shrinkage	2.4	1.8.
Porosity	30.5	19.8.
Cone 1:		
Color	Light yellow	Buff.
Condition	Very hard	Steel hard.
Shrinkage	3.5	3.8.
Porosity	25.7	16.5.
Cone 3:		
Color	Light yellow	Buff.
Condition	Very hard	Steel hard.
Shrinkage	3.2	3.6.
Porosity	25.3	18.0.
Cone 5:		
Color	Light yellow	Gray-buff.
Condition	Steel hard	Steel hard.
Shrinkage	5.3	3.9.
Porosity	23.5	14.1.

The following is a chemical analysis of sample UT 28, 29:

SiO_2	73.70	K_2O	1.48
Al_2O_3	15.82	TiO_2	.55
Fe_2O_3	1.41	CO_2 and H_2O	3.88
CaO	.94		
MgO	.94	Total	99.54
Na_2O	.72		

The following is Lawton's record of the 12-foot test pit, that was put down at the time of the San Antonio Chamber of Commerce investigation:[81]

One sample from the property examined by Mr. Lawton is classed by him as brick clay (SA 409), four as brick and tile clays (SA 406, 408, 413, and 416), three as brick, tile, and terra cotta clays (SA 157, 407, and 411), and three as refractory clays (SA 410, 412, and 415).

[81] San Antonio Chamber of Commerce, op. cit., p. 61.

Tests of clay from 12-foot pit on F. H. Weber farm

Depth	Raw color and composition	On firing to 2,000° F.			On firing to 2,200° F.			On firing to 2,390° F.		
		Color	Shrinkage in 8 inches (inch)	Warping	Color	Shrinkage in 8 inches (inch)	Warping	Color	Shrinkage in 8 inches (inch)	Warping
Ft. in. Ft. in.										
0 0 to 2 8	Grayish and brown; 90 percent sand, 10 percent clay.	Light lavender	1/4	None	Buff	1/4	None	Dark gray	1/4	None.
2 8 to 4 0	Gray and blue; 95 percent clay, 5 percent sand.	Light buff	1/2	do	Brownish buff	3/16	do	Grayish buff	5/8	Do.
4 0 to 4 8	Bluish gray	Light pinkish buff	1/4	do	Buff	5/16	None	do	3/8	Do.
4 8 to 6 4	Bluish brown; 100 percent clay	Brownish buff	1/4	Slight	Dark buff	3/8	Slight	Vitrified		
6 4 to 7 3	Light brown; 95 percent sand, 5 percent clay.	Light brown	None	None	Light reddish brown.	None	None	Brown	None	Do.
7 3 to 8 5	Brownish gray; 90 percent clay, 10 percent sand.	Pinkish buff	3/4	Slight	Brownish buff	7/8	do	Brownish buff	15/16	Do.
8 5 to 9 1	Grayish brown; 95 percent sand, 5 percent clay.	Gray	None	None	Gray	None	do	Dark gray	None	Do.
9 1 to 9 11	Brown and yellow; 100 percent clay	Brown and purple	13/16	do	Reddish brown	3/4	do	Vitrified		
9 11 to 10 2	Soft sandstone and rock									
10 2 to 11 4	Brownish gray	Bluish brown	11/16	None	Dark buff	3/4	do	Dark buff	15/16	Do.
11 4 to 12 0	do	Gray	None	do	Gray	None	do	Dark gray	None	Do.

Vogt deposit.—Clays are found on the Anton J. Vogt farm, southwest of the village of Von Ormy, southwest of San Antonio, in the West San Antonio quadrangle (pl. 4). The deposits of particular interest lie near the windmill in his south pasture, 1.7 miles southwest of the village, between the Benton City and Edwards Roads on the

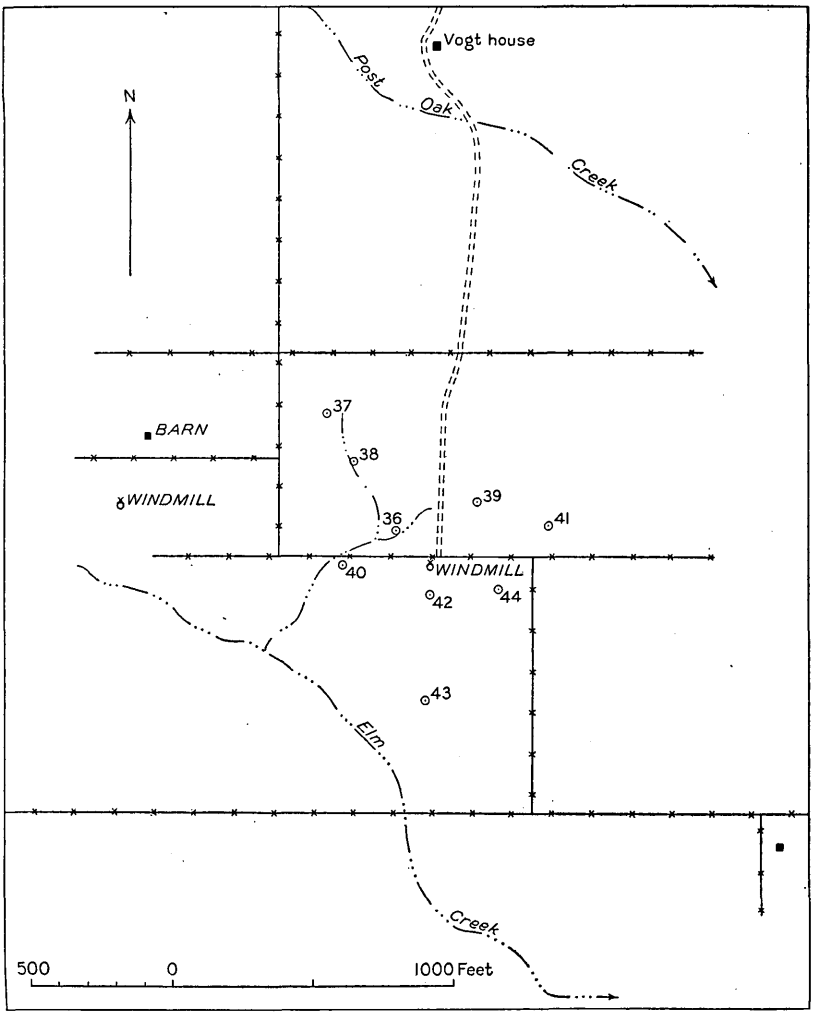


FIGURE 12.—Map of Vogt farm, Bexar County, Tex., showing location of test holes.

east and west and Post Oak and Elm Creeks on the north and south (fig. 12). This lies in an extensive area of down-faulted rocks of the Wilcox group. The exposures on the farm may, however, be near the base of the Wilcox, for the well at the windmill entered chocolate-colored clays with carbonaceous seams at a depth of 40 feet and encountered greensand at the bottom of the hole, at 53 feet.[82] Green-

[82] Quoted from memory by Mr. Vogt; the original log of the well has been lost.

sands are generally considered indicative of the Midway group, which underlies the Wilcox.

Most of the surface in the pasture is covered by reddish sandy clay, full of chips and fragments of very limonitic sandstone. At several places south of the windmill large blocks and ledges of the limonitic sandstone are found, showing that they are the weathered product of lenticular beds. Immediately north of the windmill a ravine has dissected the surface into small badlands, and here there are some cuts of white clay, which show a good many calcareous nodules near the surface.

A test hole put down near one of these exposures (GS 36), 200 feet north of the windmill, shows an overburden of 3 feet of sandy brown clay, beneath which are 6 feet of white clays. These grade down into 6 feet of iron-stained sandy clay and sand. The lower 14 feet of the hole is in a blue-gray carbonaceous lustrous clay, with some seams of sand and with ferruginous stains.

These two clay beds are found in other test holes, but they vary in character. In a test hole (GS 38) 300 feet northwest of the first, the upper white clays have passed into gray, yellow, and reddish sands, with only a few streaks and thin beds of white clay. To the southwest the upper bed has apparently been removed by erosion and only the lower one, 5 feet thick, is present, underlain by yellow sand (GS 40). In a test hole 600 feet to the east (GS 41), the upper bed has changed to a white sandy, limy clay. South of the windmill, four test holes (GS 40, 42, 43, and 44) show variegated sands and sandy clays in alternating thin beds.

According to McKnight, the clay samples collected by the Geological Survey party show the following features:

The seven test holes dug on this property reveal a number of distinct clay beds, none of which appear to be particularly extensive. Most of them are impaired in value by the presence of lime. The two samples covering the interval from the surface to a depth of 4 feet at locality GS 36 contain so much that the fired test pieces are very soft and crumble to pieces through slaking of the lime when they are exposed to the air.

The dark-gray clay found between 12 and 24 feet in the same hole burned to good buff bodies in the preliminary tests, and the six samples covering this interval were combined into two sets of three each for complete tests. The first set (UT 36–38, from 12 to 18 feet) burned steel hard, with color deepening with increase of temperature, and showed incipient vitrification at cone 5. In the second set (UT 39–41) the presence of excessive amounts of lime was again evident in the bloating of all pieces fired to cone 06 and above. This would condemn the clay for anything but cheap common brick.

The clay found in the bank of the ravine above the top of the test hole at locality GS 36 burns to a near white color, but the hardness attained even at higher temperatures is not sufficient to make it of any value. Because of its good color and firing behavior it might be of interest in admixture with other clays for common pottery, but since no suitable clays for such mixture are found at this location, this possibility was not further investigated in this work.

66911—40——9

The mottled orange and gray clay found at the bottom of the hole at locality GS 39 would probably make good common brick fired at about cone 1, providing the bed were found to be of sufficient extent. The bed does not seem to be penetrated in the other test holes.

The gray clay found at locality GS 44 was given a complete test (UT 62–63) and because of evidence of refractory properties was analyzed chemically. It was found to burn to a good light color and hard body, but its shrinkage and porosity behavior is a little erratic. The chemical analysis shows the presence of too much fluxing matter for anything but low-grade refractories.

The following are the results of tests made by the Bureau of Industrial Chemistry on samples collected by the Geological Survey party:

Tests on clays from Vogt farm

Preliminary tests

Depth (feet)	Raw color	Shrinkage (percent)		Fired color	Fired condition	UT laboratory No.
		Drying	Firing			
GS 36						
0–2	Light gray	3.5	0.0	White	Soft; slaked on standing	30
2–4	do	3.5	.0	do	do	31
4–6	do	2.5	.0	Light pink	Poor	32
6–7	do	2.5	−.5	do	do	33
7–11	Brown	2.5	−.5	Light red	do	34
11–12	Dark gray	6.5	2.0	Pink	Good	35
12–14	do	8.5	3.5	Buff	do	36
14–16	do	8.5	4.0	do	do	37
16–18	do	9.5	4.0	Dark buff	do	38
18–20	do	9.5	5.0	do	do	39
20–22	do	11.5	4.5	Buff	do	40
22–24	do	12.0	5.5	do	do	41
24–25	Brown-gray	9.5	5.0	Brown-red	do	42
2 feet above top of hole.	Light gray	4.0	.5	Near white	Fair	43
GS 38						
0–2	do	3.0	.0	do	do	44
2–4	do	2.0	.0	Light pink	Poor	45
4–6	Orange	2.0	−4.5	Red	do	46
6–8	Orange and gray	5.5	2.5	do	Good	47
8–10	Light gray	6.5	3.5	Buff	do	48
GS 39						
4–6	do	3.5	1.5	Near white	Fair	49
6–10	Not tested; too sandy					
10–12	Light gray	2.0	−1.0	Pink	Poor	50
12–13	Purplish	3.0	−.5	Tan	do	51
13–15	Orange and gray	5.0	2.5	Light red	Good	52
GS 40						
2–5	Brown-gray	9.5	5.0	do	do	53
GS 42						
2–4	Light red	2.5	−1.5	Red	Poor; sandy	54
4–6	Gray and buff	2.0	−.5	Buff	Poor	55
6–8	Gray	2.5	.0	Pink	do	56
8–11	Gray and red	2.5	−.5	do	do	57
11–15	Purplish	1.5	.0	Light red	Poor; sandy	58
GS 43						
6–8	Brown and gray	8.5	3.5	Red	Good	59
8–10	Yellow and gray	9.0	3.0	do	do	60
10–11	Yellow	5.0	.5	Purple	Poor	61
GS 44						
5–8	Gray	4.5	2.0	Near white	Good	62
8–11	do			Pink	Fair	63

Tests on clays from Vogt farm—Continued

Complete tests

	UT 36–38	UT 39–41	UT 48	UT 52	UT 62–63
Dry color	Dark gray	Dark gray	Light gray	Orange gray	Gray.
Hardness	Soft	Soft	Medium	Soft	Soft.
Plasticity		High	High	Medium	High.
Shrinkage water	13.9	18.1	10.2	9.6	6.1.
Pore water	10.5	9.9	11.9	11.4	13.4.
Water of plasticity	24.4	28.0	22.1	21.0	19.5.
Drying shrinkage	24.4	32.3	20.7	19.1	12.5.
Cone 010:					
Color	Pink	Pink	Light buff	Light red	Pink.
Condition	Steel hard	Steel hard	Steel hard	Very hard	Hard.
Shrinkage	2.5	−8.1	3.1	0.0	−5.2.
Porosity	25.1	16.0	26.5	26.7	32.9.
Cone 08:					
Color	Pink	Pink [1]	Light buff	Light red	Pink.
Condition	Steel hard	Steel hard	Steel hard	Very hard	Hard.
Shrinkage	4.9	−7.1	4.4	0.6	−2.9.
Porosity	21.1	12.8	25.3	27.1	33.9.
Cone 06:					
Color	Pink	Pink [2]	Buff	Light red	Light pink.
Condition	Steel hard	Steel hard	Steel hard	Very hard	Hard.
Shrinkage	9.7	−17.3	6.9	3.29	−4.0.
Porosity	15.2	12.1	19.9	23.0	33.1.
Cone 04:					
Color	Pink	Brown [2]	Buff	Light red	Light pink.
Condition	Steel hard	Steel hard	Steel hard	Steel hard	Hard.
Shrinkage	7.7	−13.2	11.3	4.1	−1.8.
Porosity	16.1	17.7	18.2	23.3	33.6.
Cone 02:					
Color	Pink	Brown [2]	Buff	Light buff	Near white.
Condition	Steel hard	Steel hard	Steel hard	Steel hard	Hard.
Shrinkage	12.1	−31.6	13.8	4.6	−0.5.
Porosity	12.7	19.8	14.9	21.8	31.4.
Cone 1:					
Color	Light brown	Brown [2]	Gray-green [3]	Buff	Buff.
Condition	Steel hard	Steel hard	Steel hard	Steel hard	Very hard.
Shrinkage	14.2	−43.0	16.3	6.2	2.2
Porosity	15.5	19.5	7.6	17.4	29.5.
Cone 3:					
Color	Light brown	Brown [2]	Gray-green [3]	Buff	Light buff.
Condition	Steel hard	Steel hard	Steel hard	Steel hard	Steel hard.
Shrinkage	14.6	−5.7	15.3	5.3	0.7.
Porosity	10.2	8.9	10.9	19.2	30.4.
Cone 5:					
Color	Gray-brown	Gray [2]	Gray-green [4]	Buff	Light buff.
Condition	Steel hard	Steel hard	Steel hard	Steel hard	Steel hard.
Shrinkage	13.5	−41.9	17.2	6.4	7.3.
Porosity	10.6	13.0	7.6	15.8	28.1.

[1] Cracked.
[2] Bloated.
[3] Incipient vitrification.
[4] Vitrified.

The following chemical analysis was made by the Bureau of Industrial Chemistry on the combined sample UT 62–63:

SiO_2	68.20	Na_2O and K_2O	0.56
Al_2O_3	16.89	TiO_2	.92
Fe_2O_3	1.57	CO_2 and H_2O	7.94
CaO	1.27		
MgO	1.33	Total	99.68

Samples from another deposit near Von Ormy were submitted to the San Antonio Chamber of Commerce by V. L. Cromwell. This deposit was not visited by the Geological Survey party. Three samples were classed by Lawton as brick, tile, and pottery clay of best quality (SA 359, 360, 361), but four samples were rejected because they contained too much lime (SA 355, 356, 357, and 358).

Deposits near Atascosa.—At Atascosa (Stumberg) station on the International-Great Northern Railway, southwest of San Antonio, in the West San Antonio quadrangle (pl. 4), the Meyer Pottery Co. makes flower pots, vases, and dishes from clays dug in the vicinity. The pottery has been in operation for more than 30 years. The clay deposits are probably in the middle or upper part of the Wilcox group.

According to G. L. Meyer, the clays first used by the pottery came from a cut bank of Elm Creek about a mile north of Atascosa. This has since been covered by stream deposits. Later, clays were dug from the railroad right of way to the northeast. At the time of Ries' visit the pottery was using clay from the property of U. G. McDonald, 1¼ miles east of Atascosa.[83] At that place a bed about 6 feet thick was being worked. It was overlain by pockets of sandy clay and underlain by white clay; it graded laterally into ferruginous sandstone. None of these deposits were visited by the Geological Survey party.

The clays used at present are taken from deep ravines cut by Black Hill Branch and its tributaries three quarters of a mile southeast and east of the plant. Here they are overlain by 6 to 10 feet of loesslike overburden, but as the digging is confined to small pits along the stream banks, this ordinarily does not have to be removed. Directly beneath the overburden the clays are somewhat impregnated with lime. Most exposures show about 6 feet of the clays. The clays are gray or white, all are more or less sandy, and in places they contain ferruginous concretions and lavender stains. The more argillaceous parts of the deposit are said to be lenticular and inconstant and to grade laterally into strata too sandy for use. Some sand is taken out of the clays at the plant by grinding them, mixing them with water, and allowing them to settle.

The light-colored clays in this region are underlain by darker, less sandy clays, which are tough, lustrous, and lignitic. Mr. Meyer reports that wells in the vicinity of Atascosa strike a bed of lignite 70 feet below the surface.

McKnight comments as follows on the material gathered here by the Geological Survey party:

The Meyer Pottery at Atascosa has been using a clay found in a creek bank in that vicinity. The clay bed is rather thin and spotted, and a certain amount of care has to be employed in picking the clay extracted for use at the pottery. With the relatively small amounts of clay required, this procedure is feasible, where it would be impossible in the case of a large plant or one manufacturing such ware as brick or tile.

The clay is washed to improve its quality before being used at the pottery. The two samples taken from the clay piles at the pottery are interesting in showing the effect of the washing process on the clay. The washed clay shows a marked increase in shrinkage due to the removal of nonplastic matter in the washing. The fact that the washed sample burns to a deeper color than the raw clay is probably due to the fact that the coloring matter consists of finely divided and

[83] Ries, Heinrich, op. cit., pp. 115–116.

possibly colloidal iron compounds, which are not removed in washing. The removal of sand serves to concentrate the color. It is also possible that some lime is removed in washing, and the color-masking effect of lime is therefore missing in the washed clay.

The surface sample from locality GS 50 shows favorable properties and would appear to be just as good for pottery as that now being used at Atascosa, although the shrinkage is slightly higher. The sample from locality GS 51 has an inordinately high shrinkage for pottery and not enough good points otherwise to make it useful in a pottery mixture.

The following preliminary tests were made by the Bureau of Industrial Chemistry on clays from the vicinity of Atascosa collected by the Geological Survey party:

Tests of clays from vicinity of Atascosa

GS locality	Raw color	Shrinkage (percent)		Fired color	Fired condition	UT laboratory No.
		Drying	Firing			
A	Gray	3.5	0.0	Near White	Good	21
B	do	5.0	.5	Pink	do	22
50	Light gray	5.0	3.0	Dirty yellow	Very good	97
51	Blue gray	9.5	6.0	Light brown	Good	98

A. Raw clay from clay piles at Meyer Pottery.
B. Washed clay from clay piles at Meyer Pottery.
50. Surface sample from bank of Black Hill Branch ¾ mile east of Atascosa; probably from nearly the same place as sample GS A.
51. Surface sample frompoint 1¼ miles east of Atascosa; probably the samples studied by Ries came from a locality nearby.

A sample studied by Ries (R 925) from the pit operated by the Meyer Pottery at the time of his visit showed the following results:[84]

Moist color	Light brown	Slaking power	Fast
Water of plasticity	22.0	Plasticity	High
Air shrinkage	5.8	Texture	Medium
Average tensile strength	183	Soluble salts	0.38

Firing tests

	Color	Shrinkage (percent)	Absorption (percent)
Cone 05	Light pink	2.0	11.82
Cone 03	do	1.6	12.96
Cone 1	Pink buff	3.0	9.46
Cone 3	do	4.0	7.77
Cone 5	Deep buff	4.7	4.26
Cone 9	do	4.7	3.70
Cone 14	Gray	3.0	2.50

The following chemical analysis was made of the clay:

SiO_2	65.6	K_2O	1.0
Al_2O_3	20.5	TiO_2	.3
Fe_2O_3	1.4	H_2O	7.5
CaO	1.7		
MgO	.3	Total	98.95
Na_2O	.6		

[84] Ries, Heinrich, op, cit., pp. 115-116.

Deposits near Natalia.—Farther southwest, near Natalia, in Medina County, on the line of the International-Great Northern Railway, in the Natalia quadrangle (pl. 4), thick clay deposits are reported. They probably lie near the top of the Wilcox group, and exposures of Carrizo sand are found near the town.[84a] The clays were explored at the time of the Chamber of Commerce investigation by two test pits, dug to depths of 20 and 69½ feet. The samples from the pits were tested by A. V. Lawton. The pits are "about 1,800 feet south of the railroad station, about 1,200 feet south of the main highway from San Antonio to Laredo, and in the western part of the town site of Natalia." [85]

These deposits were not explored by the Geological Survey party, but the writer made a brief examination of the surface features in and near the town site. The uplands in which the test holes were sunk are covered by loose gray sand, probably derived from nearby exposures of the Carrizo formation. Ravines west of the town expose red, brown, and gray sands, with a few beds of sandy clay. The first pure clay of any thickness reported by Lawton came from a depth of 35 feet in the deeper test hole, below which pure clays continue to the bottom of the hole. Production from this clay bed would probably have to be obtained north of the town site, up the dip of the strata, as the overburden is too great at the point where the test holes were dug. An effort was made to determine whether the clay bed crops out in this direction, but no exposures were found nearer than a mile north of the railway station. At this point a southward-dipping sandstone bed forms a ledge that strikes east and west. It probably underlies the clay bed.

The following is a record of the materials penetrated in the two test holes, and the results of tests on them by Lawton:[86]

[84a] Sayre, A. N., Geology and ground-water resources of Uvalde and Medina Counties, Tex.: U. S. Geol Survey Water-Supply Paper 678, pl. 1, p. 10, 1936.
[85] San Antonio Chamber of Commerce, op. cit., p. 59.
[86] San Antonio Chamber of Commerce, op. cit., pp. 62–63.

Tests of clays near Natalia

Pit No. 1

Depth	Raw color	Percent of clay and sand	On firing to 2,000° F.			On firing to 2,200° F.			On firing to 2,400° F.		
			Color	Shrinkage in 8 inches	Warping	Color	Shrinkage in 8 inches	Warping	Color	Shrinkage in 8 inches	Warping
Ft. in. Ft. in.				*Inches*			*Inches*			*Inches*	
0 to 6	Yellow, red, brown, and gray.	10 clay, 90 sand.	Light brown	1/8	None	Light brown	1/8	None	Light brown	1/4	None.
6 to 11	Yellow and gray	25 clay, 75 sand	Brownish	1/4	do	Dark buff	1/4	do	Brown-buff	3/8	Do.
11 0 to 14 3	do	40 clay, 60 sand	Purplish brown	1/4	do	Reddish brown	1/4	do	Reddish brown	3/8	Do.
14 3 to 15 8	Yellow and blue	90 clay, 10 sand	Light brown	13/16	do	Brownish buff	1	do	Brownish buff	1 1/4	Do.
15 8 to 17 3	Yellow, blue, and gray.	60 clay, 40 sand	do	5/16	do	Light brown	7/16	do	do	5/8	Do.
17 3 to 22 9	Streaked blue, white, and yellow.	90 clay, 10 sand	Pinkish buff	11/16	do	Buff	7/8	do	Buff	1 1/16	Do.
22 9 to 25 3	Yellow, blue, and gray.	60 clay, 40 sand	Pinkish gray	3/8	do	do	7/16	do	do	1/2	Do.
25 3 to 30 2	Yellow, brown, and gray.	do	Gray	1/2	do	do	1/2	do	do	9/16	Do.
30 2 to 30 7	Brown and white	100 clay	Pinkish buff	5/8	do	Dark buff	7/8	do	Dark buff	1	Do.
30 7 to 35 9	Brown and gray	60 clay, 40 sand	Brownish gray	9/16	do	Buff	11/16	do	Buff	3/4	Do.
35 9 to 40 0	Soft red rock; locally developed.										
40 0 to 42 2	Black, streaked with white.	100 clay	do	11/16	Slight	Brownish buff	1 1/16	Slight	Brownish buff	1 1/8	Do.
			On firing to 1,950° F.			**On firing to 2,250° F.**			**On firing 2,350 ° F.**		
42 2 to 44 0	Black, streaked with yellow.	do	Buff	15/16	None	Brownish buff	15/16	None	Dark brown	1 1/8	Practically none.
44 0 to 50 8	do	do	Brownish buff	15/16	do	Reddish buff	15/16	do	Dark chocolate brown.	1 1/8	None.
50 8 to 58 5	do	do	Dark buff	15/16	do	Reddish brown	15/16	do	Dark chocolate brown. Vitrified.	1 1/8	Do.
58 5 to 64 5	do	do	Buff	1	Slight	Dark brown	1	do	do	13/16	Do.
64 5 to 65 5	do	do	do	7/8	None	Brown	15/16	do	do	1	Slight.
65 5 to 66 2	do	do	Brown	3/4	do	Dark brown	3/4	do	Dark chocolate brown.	13/16	Do.
66 2 to 69 5	do	do	Brownish buff	1 5/16	do	Reddish brown	1 5/16	do	do	15/16	Do.

Tests of clays near Natalia—Continued

Pit No. 2

Depth	Raw color	Percent of clay and sand	On firing to 2,000° F.			On firing to 2,200° F.			On firing to 2,400° F.		
			Color	Shrinkage in 8 inches	Warping	Color	Shrinkage in 8 inches	Warping	Color	Shrinkage in 8 inches	Warping
Ft. in. Ft. in.				*Inch*			*Inch*			*Inch*	
0 0 to 7 7	Red, yellow, brown, and gray.	15 clay, 85 sand	Reddish brown	3/8	Slight	Reddish brown	7/16	Very slight.	Red	7/16	None.
7 7 to 10 0	Light brown and gray.	15 clay, 85 sand	do	3/8	Very slight.	Brown	7/16	Slight	Reddish brown	7/16	Do.
10 0 to 11 9	Gray, yellow, and brown.	10 clay, 90 sand	Pinkish brown	7/16	None	Buff	5/8	None	Buff	13/16	Do.
11 9 to 15 7	Gray, yellow, brown, and purple.	95 clay, 5 sand	Salmon	9/16	do	Brown	13/16	Slight	Brownish buff	13/16	Do.
15 7 to 16 8	Yellow and purple	95 clay, 5 sand	Light purple	1/2	do	Buff	5/8	do	do	13/16	Do.
16 8 to 18 3	Yellow	5 clay, 95 sand	Brownish buff	5/16	do	Light brown	7/16	None	Light brown	7/16	Do.

CLAYS FROM UPPER PART OF WILCOX GROUP

In southeastern Bexar County there are several deposits that lie immediately or a short distance below the contact of the Carrizo sandstone and the Wilcox group. A few of these deposits belong to the upper marine beds of the Wilcox, but most of them appear to be of nonmarine origin. The rather widespread occurrence of clays in the highest Wilcox in this part of the county is sufficiently significant to warrant their description under a separate heading from the other Wilcox deposits.

Deposits near Saspamco.—North of Saspamco, not far northwest of the Bexar-Wilson County line, clays have been dug at numerous places by the San Antonio Sewer Pipe & Manufacturing Co. (pl. 4). Most of the pits are or have been connected with the plant at Saspamco by a line of industrial railway. The uplands in this vicinity are capped by outliers of the Carrizo sand, and the clays are dug from the beds immediately beneath. About a quarter of a mile southeast of Saspamco, in the Saspamco quadrangle, are large pits operated by a San Antonio concern, from which sands of the Carrizo are dug and shipped for use in building.

The northernmost clay pit that has been operated lies about 4 miles north of Saspamco, near Chupaderas Creek and on the north side of the Adkins-Elmendorf road, in the East San Antonio quadrangle. It has not been worked for nearly 15 years. The main pit, north of the road, is about 400 feet long, 75 feet wide, and 20 to 30 feet deep. South of the road are smaller pits on the east bank of the creek. The deposits at this place belong to the upper marine beds of the Wilcox group, and consist of laminated dark-gray, black, and brownish clays, all slightly sandy, interbedded with thin seams of soft gray sand. In the upper part of the pit is a series of lenses of hard calcareous sandstone and some cone-in-cone concretions. The clays were stripped off to the base of the marine layers, but the basal marine beds are not exposed in the main pit. In the smaller pits south of the road these are exposed and consist of a thin conglomerate, with pebbles and fossils.

Another large pit lies farther south, about 1½ miles east of Elmendorf, in the East San Antonio quadrangle. This is shown on the map (pl. 4) as the "Ermler clay pits." It is probably the pit that has been described by C. L. Baker,[87] who says:

> The overburden at the pit * * * is a cross-bedded sand from 10 to 12 feet thick. The upper 6 to 8 inches are light gray, below which is found 4 feet of light brick-red sands, while the remainder beneath is a light brownish red. The sands are often mottled with red. * * * This overburden is removed by steam shovel. The dip in this pit as indicated at the contact between these sands and the underlying clays is 1° S.

[87] Sellards, E. H., op. cit., p. 113.

The total thickness of the clay worked at this pit is about 18 feet. The clay is blue drab in color and slakes on long exposure to the weather. It weathers in bedding planes and joint cracks, with a rusty to brick-red coating of limonite. It contains small nodules of limonite and stains of yellow alum. It contains also many well-preserved fossil plant impressions, especially leaves of dicotyledonous plants.

The overburden of the pit would seem to be the Carrizo sand, and the underlying clays are without doubt the highest beds of the Wilcox group, here apparently of nonmarine origin.

Older pits, first worked by the sewer-pipe company, dot the hills nearer to Saspamco. The pit being worked at the time of Ries' visit was one-eighth of a mile from the plant.

Ries [88] gives the following notes on the pits nearest Saspamco:

The formation involves a series of speckled shaly clays interstratified with occasional beds of sandstone and ocherous clay. Owing to the somewhat lenticular character of the clay deposits, new beds have to be opened up from time to time as the old ones are worked out. The section in the bank that was being worked at the time of the writer's visit [1903] was as follows:

	Feet
4. Surface clay, sandy, laminated, iron-stained	4
3. Clay, chocolate	8
2. Clay, yellow, ferruginous (rejected)	1
1. Clay, chocolate, dense, tough	7

The beds dip gently to the westward, and the deposit whose section is here given can be followed at least 1,500 feet to the north, where it dies out. Lying to the northeast and west respectively are two other pockets of clay, and one large pocket near the works has been exhausted.

A sample taken from the pit described above (R 807) was determined by Ries to have the following properties:

Water of plasticity	30.8	Plasticity	High
Air shrinkage	10.2	Slaking	Slow
Average tensile strength	257	Texture	Dense, homogeneous
Soluble salts	0.24	Moist color	Brown

Firing tests

	Color	Shrinkage	Absorption
Cone 05	Buff	1.6	11.44.
Cone 03	do	2.7	9.52.
Cone 1	do	3.3	6.57.
Cone 3	do	5.6	2.35.
Cone 5	do	5.7	2.83.
Cone 9	Gray	9.4	0.82.
Cone 12	do	Swells	Beyond vitrification.
Cone 28	Viscous		

The following chemical analysis of sample R 807 was made for Ries:

[88] Ries, Heinrich, op. cit., pp. 118-119.

SiO_2	64. 92	K_2O	0. 12
Al_2O_3	22. 70	TiO_2	1. 40
Fe_2O_3	. 80	H_2O	7. 00
CaO	. 10		
MgO	. 74	Total	98. 49
Na_2O	. 71		

Related deposits.—Clays probably similar to those near Saspamco are reported to occur to the southeast, along Calaveras Creek near the village of Calaveras, in the Saspamco quadrangle (pl. 4). It should be noted, however, that the clays which were used at the old brick yards near Calaveras are Recent river deposits.

According to Ries,[89] a bed of clay outcrops on the property of Mr. Cassiano on Calaveras Creek, just west of the railroad bridge at Calaveras, and shows the following section:

	Feet
3. Overburden	8–10
2. Stratified clay	5–7
1. Covered to creek level	15

A sample from this place tested by Ries (R 810) showed the following properties:

Water of plasticity	28. 6	Plasticity	Good
Air shrinkage	6. 9	Slaking	Slow
Average tensile strength	191	Texture	Dense, laminated
Soluble salts	. 24	Color	Brownish

Firing tests

	Color	Shrinkage (percent)	Absorption (percent)
Cone 05	Buff	4. 0	10. 49
Cone 03	Pink-buff	5. 0	8. 73
Cone 1	Buff	6. 7	5. 49
Cone 3	do	6. 7	5. 28
Cone 5	Gray-buff	8. 0	0. 76
Cone 9	Nearly viscous		
Cone 12	Viscous		

The following chemical analysis of sample R 810 was made for Ries:

SiO_2	70. 5	K_2O	Trace
Al_2O_3	18. 3	TiO_2	1. 2
Fe_2O_3	1. 8	H_2O	5. 5
CaO	Trace		
MgO	. 9	Total	98. 4
Na_2O	. 2		

A deposit probably closely related to the clays of the Ermler pits lies about half a mile to the north, 1½ miles east-northeast of Elmendorf on the Elmendorf-Lavernia road, in the East San Antonio quadrangle (pl. 4). It is known locally as the Bell clay pit, and the clay is said to have been used by the Star Products Co. at Elmendorf from

[89] Idem, pp. 154–155.

1919 to 1922.[90] The pit here is relatively small, at least by comparison with the same company's pits at Borrego, described below. At the top of the pit is 5 feet of brown sandstone, possibly of Carrizo age, below which is interbedded clay and gray sand, but the lower part of the pit is buried by cavings. The beds dip at an angle of a few degrees to the southeast.

Borrego pits.—About 4 miles south-southwest of Elmendorf, on the south side of the San Antonio River bottoms, in the Saspamco quadrangle, are the main pits used by the Star Products Co. and its predecessors [91] at Elmendorf (pl. 4). The pits are south of the settlement of Borrego and about half a mile off the Rockport Road. They were at one time connected with the company's plant at Elmendorf by an aerial tramway, but this was dismantled about 15 years ago. At the present time some clay is hand-picked from layers of good quality in the western of the two groups of pits and is hauled by truck to the San Jose Pottery and to the tile plant of the Southern Co. in San Antonio.

The pits lie along the south edge of the San Antonio River bottom, on the slope of a low escarpment capped by Carrizo sandstone. The eastern group of pits, which lie at the former terminus of the old aerial tramway, are cut into the north, east, and south sides of a more or less detached spur of the Carrizo escarpment. The pit on the north side is the largest and exposes 15 feet of beds. A pool at the southeast side is said to fill an excavation which is 20 feet deeper.[92] In this pit the dip is about 8° S. The clays and sands appear to have been stripped down to a layer of ferruginous ripple-marked sandstone, which crops out on the north side of the pit and descends beneath the pool to the south. The beds above this layer are very sandy white well-bedded clays, with some thin interbedded sandstone layers and several thicker brown sandstone beds toward the top. There are a few thin beds of white clay with a relatively small amount of fine sand. In the field the beds below the layer that has been stripped do not seem to be greatly different from those that were used, but apparently they were too sandy for use.

In the pit on the east side of the hill these strata are overlain by 5 to 8 feet of soft brown, very irregularly bedded sandstone, which contains irregular lumps of white clay, possibly reworked from the beds below. Above this are ledges of massive reddish-brown quartzite, containing coarse sand grains, which are the basal beds of the Carrizo formation. The pit on the south side of the hill is similar to that in

[90] Information from H. B. Parks.
[91] Ries (op. cit., p. 118, 1903) speaks of the firms of Saenger & Son and E. Richter as operating at Elmendorf.
[92] Information from H. B. Parks.

the north pit but contains beds a few inches to a few feet thick of pure gray clays.

The beds exposed in these pits and immediately underlying the Carrizo seem clearly to be of nonmarine origin. The marine beds of the Wilcox group found at other places are wanting, through either nondeposition or pre-Carrizo erosion.

The western group of pits lies about a quarter of a mile west of the first group, on the farm of Mrs. Linn. These pits were operated before the aerial tramway was built and for a time after its abandonment.[93] The main pit here is 300 feet long north and south and 75 feet wide east and west. The strata are similar to those in the eastern group of pits but lack the capping of Carrizo sandstone. In the lowest strata, exposed at the north end of the pit, are two or three layers of gray nonsandy clay, as much as 1 foot thick, which are now being stripped off and hand-picked for use in San Antonio.

According to Baker,[94] this same method was also employed by the Star Co. when it needed clay for the making of jugs, crocks, and flower pots.

The following tests on surface samples collected by the writer were made by the Bureau of Industrial Chemistry. The samples were selected in the field as representing the best clays in the deposits. The sample from Mrs. Linn's property is of the type now being used by potteries in San Antonio.

Tests of clays near Borrego

Locality	Raw color	Shrinkage (percent)		Fired color	Fired condition	UT Laboratory No.
		Drying	Firing			
A	Light gray	7.5	2.5	Near white	Very good	104
B	White	7.0	3.0	Dirty white	do	105
C	Light gray	4.5	1.0	Light pink	Good	106

A. Western Borrego pit, on Mrs. Linn's property.
B. Eastern group of Borrego pits; south pit.
C. Eastern group of Borrego pits; west side of north pit.

Clay being used at Elmendorf at the time of Ries' study (1903) was tested by him, with the results quoted below (R 808).[95] This material possibly came from the Linn pit at Borrego.

Water of plasticity	20.9	Plasticity	Good
Air shrinkage	6.8	Slaking power	Slow
Average tensile strength	245	Texture	Dense, homogeneous
Soluble salts	0.38	Color	Light brown

[93] Information from J. R. Martin, a former partner in the Star Co.
[94] Sellards, E. H., op. cit., p. 113.
[95] Ries, Heinrich, op. cit., pp. 116–118.

Firing tests

	Color	Shrinkage (percent)	Absorption (percent)
Cone 05	Light buff	1.7	10.5
Cone 03	Buff	1.3	11.31
Cone 1	Buff	3.4	8.69
Cone 3	Buff	4.0	6.34
Cone 5	Buff	4.3	6.35
Cone 9	Buff	4.4	2.29
Cone 14	Gray	4.0	
Cone 27	Viscous		

The following chemical analysis was made of this sample for Ries:

SiO_2	68.3	K_2O	Trace
Al_2O_3	20.1	TiO_2	1.2
Fe_2O_3	1.0	H_2O	6.6
CaO	Trace		
MgO	2.4	Total	100.2
Na_2O	.6		

Related deposits.—Other deposits of clay probably occur along the Carrizo escarpment that fringes the south side of the San Antonio River bottom in this neighborhood. According to J. R. Martin, clays similar to those at Borrego are found farther east on the Gillette farm, which lies on the east side of the road about a mile south of the old plaza at Graytown, in the Saspamco quadrangle (pl. 4). This district was examined briefly by the writer, but except for some ledges of Carrizo sandstone on the hilltops, all the bedrock was covered by drifted sand.

Some clays from 2 to 2½ miles west of Elmendorf (and thus presumably north of the San Antonio River) were examined by A. V. Lawton for the San Antonio Chamber of Commerce, but two samples are considered by him to be medium to poor quality brick clays (SA 133 and 176) and one sample was rejected because the test pieces crumbled (SA 177).

Brotze deposit.—About 4 miles south of the village of Losoya, on the east side of the Campbellton Road, in the Saspamco quadrangle, is the clay pit of Otto Brotze (pl. 4). This is about 5 miles southwest of the Borrego pits and lies well within the hills of the Carrizo formation. Most of the surrounding country is covered by drifted sand, reworked from the sandstones of this formation. At this place, beneath the drifted sands, are reddish, slightly consolidated sandstones with large quartz grains of the characteristic aspect of the Carrizo sandstones. The clays in the pit project like a hill into the sandstones, and the sandstones dip north and south away from them perhaps by original dip off an unconformable surface.

The upper beds in the pit consist of 6 feet of fine-grained ripple-marked argillaceous sandstone of gray and buff colors, but with some brown iron seams. This is interbedded with and interfingers with the underlying clays in the lower part. Beneath is 6 feet of white nonsandy clay to the bottom of the pit, and 5 feet more is locally reported to have been penetrated beneath it.

The stratigraphic position of this clay bed is open to some doubt. It lies well within the area of outcrop of the Carrizo, which is characteristically a nonargillaceous formation. The unconformable relations of the undoubted Carrizo on the clay beds in the pit suggests that the clays may lie on the projecting summit of a buried hill composed of Wilcox strata.

The following tests were made by the Bureau of Industrial Chemistry on samples collected by the Geological Survey party (GS 66):

Tests of clay from Brotze deposit

	Raw color	Shrinkage percent		Fired color	Fired condition	UT labora-tory No.
		Drying	Firing			
A	White	6.5	0.5	Very light yellow	Very good	20
B	Red and gray	4.5	.0	Red	Fair	135
C	Gray and brown	5.5	1.5	Light red	Good	136
D	Light gray	7.0	2.0	Pink	do	137
E	Gray	7.0	1.5	Light yellow	do	138

A. Average sample for whole pit.
B. Uppermost clay of pit.
C. Average of upper 6 feet of clay.
D. 3 feet below sample C.
E. Basal 4 feet in pit.

On pape 134 is a record of samples from a test hole put down under Mr. Lawton's direction at the time of the investigation of the San Antonio Chamber of Commerce.[96]

Clay near Losoya.—The following is the record of a test made by the Bureau of Industrial Chemistry on a sample of clay from an exposure on the bank of Losoya Creek just above the bridge of the South Flores Road, half a mile south of the village of Losoya, in the Saspamco quadrangle (pl. 4). The clays at this place have been described in several geologic reports[97] and are the upper marine beds of the Wilcox group. Their basal layers, consisting of indurated fossiliferous conglomerate, are exposed in the channel of the stream. Tests of sample UT 99 gave the following results:

Raw color, brown-gray; shrinkage on drying, 10.0 percent; on firing, 3.0 percent; fired color, red; fired condition, very good.

According to McKnight, the clay has high plasticity and very good behavior, except for the very high drying shrinkage.

[96] San Antonio Chamber of Commerce, op. cit., p. 61.

[97] Sellards, E. H., op. cit., pp. 58–59, 69. Deussen, Alexander, op. cit., pp. 55–56, pl. 18, *B*. Plummer, F. B., op. cit., pp. 603–604.

Tests of clay from test hole on Brotze farm

Depth	Raw color	Percent of clay and sand	On firing to 2,000° F.			On firing to 2,200° F.			On firing to 2,390° F.		
			Color	Shrinkage in 8 inches (inches)	Warping	Color	Shrinkage in 8 inches (inch)	Warping	Color	Shrinkage in 8 inches (inches)	Warping
Ft. in. Ft. in.											
0 to 2 11	Brown with gray streaks	95 clay, 5 sand	Light buff	1 1/16	None	Light buff	3/4	None	Buff	7/8	None.
2 11 to 3 6	Dark brown	100 clay	do	3/4	do	do	7/8	Slight	do	15/16	Slight.
3 6 to 6	Brown with gray streaks	95 clay, 5 sand	do	5/8	do	do	3/4	None	do	7/8	None.
6 to 9	Light brown with gray streaks.	90 clay, 10 sand	do	3/16	do	do	5/8	do	do	3/4	Do
9 to 9 6			do	13/16	do	do	7/8	do	do	13/16	Slight.
9 6 to 13	Light brown with gray streaks.	90 clay, 10 sand	do	5/8	do	do	3/4	do	do	7/8	None.
13 to 13 4	Yellow	100 sand	Reddish brown	1/32	do						

Deposits south of Thelma.—About 2 miles south of Thelma on the west side of the Pleasanton Road in the Saspamco quadrangle, are the F. H. Lalley and Scott Williams farms (pl. 4). On the Lalley

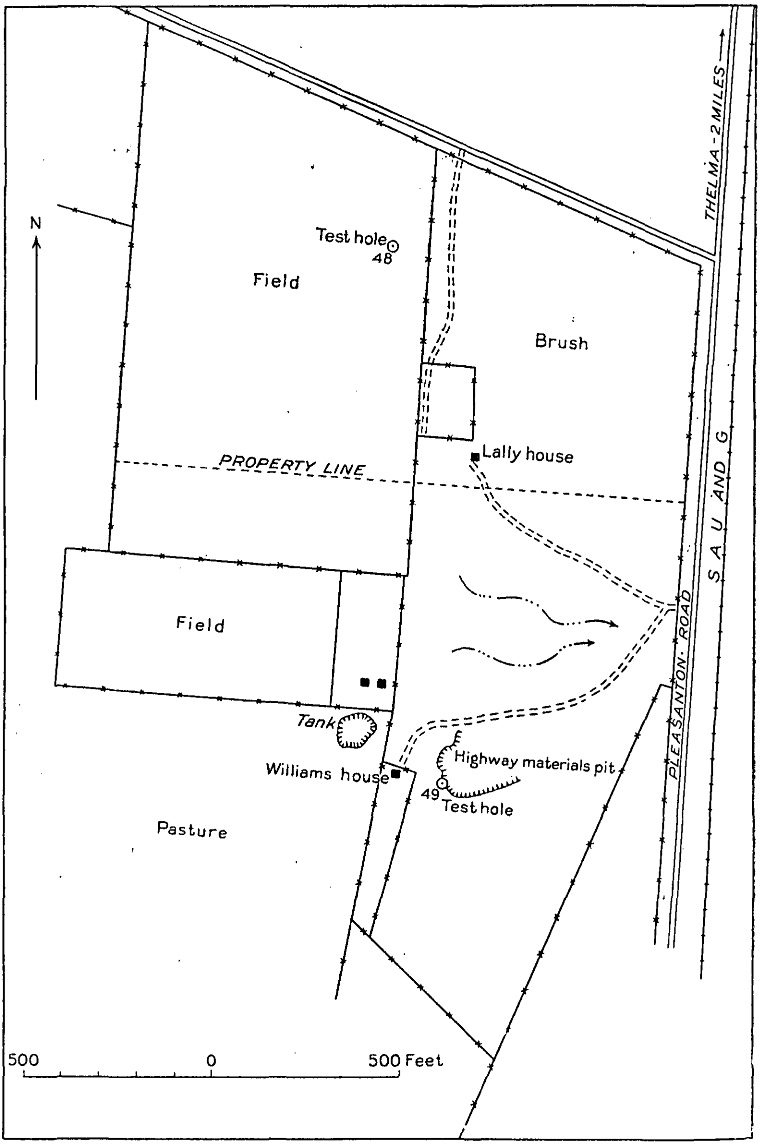


FIGURE 13.—Map of Lalley and Williams farms, Bexar County, Tex., showing location of test holes

place, which lies to the north (fig. 13), a ravine runs northwest across the west field and exposes variegated clays, overlain by white sands. A test hole (GS 48) in the northeastern part of the field showed gray, reddish, and brownish sands, in part micaceous, and some sandy clays to a depth of 18 feet. According to McKnight, the test hole "reveals a very promising clay from a depth of 6 to 12 feet. This showed very good qualities on complete test (UT 82–84). It would make good brick or tile if fired above cone 1, but the firing would have to be kept well below cone 5 to avoid incipient vitrification at that point." Farther south, near the Lalley house, an old house cellar shows massive sandstone to a depth of 12 feet.

A road-material pit has been dug just west of the Williams house and south of the Lalley place. In the upper part are coarse cross-bedded friable sandstones, which contain clay pebbles and leaf impressions.[97a] A test hole (GS 49) drilled below the sandstones showed dark-gray, yellow-brown, and chocolate-brown, finely sandy, thinly laminated clays to a depth of 19½ feet. There are a few seams of sand and a few thin seams of hard ironstone. According to McKnight,

> None of the clays are of great promise except a very dark-colored clay extending from 14 feet to the bottom of the hole. Any value this clay might have is limited by its depth, but it was thought well to examine the clay carefully. It burns to a light pink, becoming buff at higher temperatures. The hardness increases with temperature, and vitrification occurs at cone 5. There is no particular evidence of fitness over the range of firing employed, but some indication that semivitrified ware, such as stoneware, might be made at cone 5 and above.

Tests of clays from Lalley and Williams Farms

Preliminary tests

Depth (feet)	Raw color	Shrinkage (percent)		Fired color	Fired condition	UT laboratory No.
		Drying	Firing			
GS 48 (Lalley)						
Surface	Buff	3.5	1.5	Red	Poor	78
0-2	Buff and gray	4.5	.0	do	Fair	79
2-4	Light gray	2.5	.5	Pink	do	80
4-6	Red and gray	2.0	.0	do	Poor	81
6-8	Buff	3.5	.5	Light red	Good	82
8-10	Buff and light gray	4.0	.5	do	do	83
10-12	Light gray	4.5	2.5	do	do	84
12-15	do	2.0	.0	do	Fair	86
GS 49 (Williams)						
0-2	Pink and gray	5.0	.0	Pink	do	87
2-4	Orange and gray	3.5	.0	do	Poor	88
4-6	do	4.0	.0	Brick red	Fair	89
6-8	Orange	1.0	1.0	do	do	90
8-10	do	2.0	3.5	do	do	91
10-12	Light brown	5.5	3.5	Light red	Good	92
12-14	Brown	7.0	4.0	Pink	do	93
14-16	Black	6.5	2.0	Light pink	Very good	94
16-18	Dark gray	7.0	2.0	Dirty white	do	95
18-20	Black	5.5	2.0	do	do	96

It is probable that the sandstones on the Williams and Lalley places belong to the Carrizo formation and that the underlying clays, at least on the Williams place, belong to the Wilcox group. Lithologi-

[97a] Parks, H. B., and Kirn, A. J., op. cit., pp. 13–14.

cally these clays resemble upper marine beds of the Wilcox as exposed at Losoya, not far to the northeast. The Carrizo sand must overlap irregularly across the Wilcox deposits in this neighborhood, because it lies at a lower altitude to the north (up the regional dip) on the Lalley place, than it does on the Williams place, to the south.

The tests given were made by the Bureau of Industrial Chemistry on samples collected by the Geological Survey party.

Tests of clays from Lalley and Williams farms—Continued

Complete tests

	UT 82-83-84	UT 94-95-96
Dry color	Brown and light gray	Dark gray and black.
Hardness	Soft	Medium.
Plasticity	Medium	High.
Shrinkage water	6.0	8.3.
Pore water	13.5	15.2.
Water of plasticity	19.5	23.2.
Drying shrinkage	13.9	16.9.
Cone 010:		
Color	Pink	Light pink.
Condition	Hard	Hard.
Shrinkage	−1.6	−1.9.
Porosity	27.4	38.3.
Cone 08:		
Color	Pink	Very light pink.
Condition	Very hard	Hard.
Shrinkage	−1.4	−2.1.
Porosity	27.5	38.7.
Cone 06:		
Color	Pink	Very light pink.
Condition	Very hard	Very hard.
Shrinkage	0.5	1.0.
Porosity	26.7	37.3.
Cone 04:		
Color	Orange	Very light pink.
Condition	Very hard	Very hard.
Shrinkage	0.7	2.3.
Porosity	26.2	36.8.
Cone 02:		
Color	Orange	Buff.
Condition	Steel hard	Steel hard.
Shrinkage	4.9	7.0.
Porosity	27.3	35.9.
Cone 1:		
Color	Orange	Buff.
Condition	Steel hard	Steel hard.
Shrinkage	10.1	11.9.
Porosity	16.5	27.2.
Cone 3:		
Color	Orange	Buff.
Condition	Steel hard	Steel hard.
Shrinkage	10.6	14.6.
Porosity	15.4	25.2.
Cone 5:		
Color	Light chocolate brown	Gray.
Condition	Incipient vitrification	Vitrified.
Shrinkage	14.5	17.9.
Porosity	11.5	18.1.

CLAYS IN THE CARRIZO SAND OR THE REKLAW MEMBER OF THE MOUNT SELMAN FORMATION

Several deposits of clay near San Antonio lie considerably south of the belt of outcrop of the Wilcox group, and are thus evidently in higher beds. The Carrizo formation, which succeeds the Wilcox, is characteristically a sand or sandstone with very little clay. According to Miss Gardner,[98] however, lenses of clay are found near the mid-

[98] Gardner, Julia, personal communication, May 1935.

dle of the formation southwest of Bexar County. The Reklaw member of the Mount Selman formation, which succeeds the Carrizo, is predominantly clay, but its outcrops as mapped lie farther south than the deposits under discussion.

Clay pit near Lavernia.—About 3 miles south-southwest of the village of Lavernia, on the southeast side of Lavernia Hill, near Dr. Dewey's well, in the Lavernia quadrangle, is a clay pit which was used for nearly 50 years by a pottery run by G. W. Suttles[99] in Lavernia (pl. 4). The pit was not visited by the writer and is reported to be filled now with drifted sand. Ries made the following section at the pit:

	Feet
Sand, coarse, yellow	2
Clay, red, sandy	4
Pottery clay, dove-colored	9

The deposit lies well south of the Carrizo-Wilcox contact and at a much higher altitude, but north of the Carrizo-Reklaw contact as mapped. It may thus be a clay lens in the Carrizo sand. Specimens of the burned clay seen by the writer were of a uniform cream color. Ries describes the burned clay as buff with a few specks.

The clay pit and pottery have not been operated since 1922. Churns, flower pots, and bricks were made from the clay.

A specimen of the clay from the Lavernia pit (R 948) was studied by Ries, who gives the following results:

Water of plasticity	24. 2	Plasticity	High
Air shrinkage	7. 3	Slaking power	Slow
Average tensile strength	204	Texture	Hard, dense
Soluble salts	0. 76	Moist color	Brown

Firing tests

	Color	Shrinkage (percent)	Absorption (percent)
Cone 05	Deep buff	1. 3	11. 84
Cone 03	do	2. 3	9. 51
Cone 1	do	3. 3	7. 80
Cone 5	Light gray	4. 6	3. 60
Cone 9	Gray	10. 66	2. 10
Cone 27	Viscous		

A chemical analysis made for Ries is as follows:

SiO_2	68. 84	K_2O	0. 45
Al_2O_3	21. 15	TiO_2	1. 22
Fe_2O_3	1. 15	H_2O	6. 22
CaO	Trace		
MgO	Trace	Total	100. 55
Na_2O	1. 12		

[99] Spelled Littel by Ries (op. cit., pp. 119–121). The writer's information on the deposit and the old pottery came from Edgar Currie, son-in-law of Mr. Suttles.

W. J. Miller deposit.—About 22 miles south of San Antonio, in northern Atascosa County is the W. J. Miller place, 1½ miles east of the Palo Alto (Poteet) Road and 2 miles south of the crossing of that road over the San Antonio Southern Railway, in the Poteet quadrangle (pl. 4). There are no exposures in the neighborhood, the whole surface being covered by reworked and drifted sand from the Carrizo formation. The deposit lies well within the outcrop of the Carrizo formation as mapped, being about 5 miles south of the Carrizo-Wilcox boundary.[99a]

In a small flat valley between the Miller house and the railway to the west are several old pits from which clay has been dug, now largely covered by drifted sand (fig. 14). A test hole (GS 52) drilled by the Geological Survey party to a depth of 14 feet at the old pits shows a 5-foot overburden of sandy clay, beneath which is 7 feet of gray

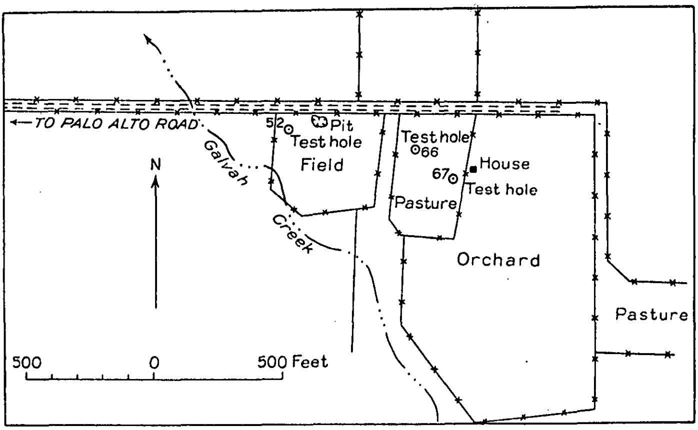


FIGURE 14.—Map of Miller farm, Atascosa County, Tex., showing location of test holes.

compact clay of the bed which is being worked. This is underlain by yellowish and reddish sands and sandy clays. Several holes, including a dug well, have been put down to the east, near the farmhouse, including one made at the time of the San Antonio Chamber of Commerce investigation, and two (GS 66 and 67) by the Geological Survey party. In this neighborhood the clay bed thickens, but the overburden also increases; one hole drilled by this party showed 8½ feet of overburden, the other 18 feet. In the first hole this was underlain by 8½ feet of compact gray clays, limy above and iron-stained below. Beneath this is blue-gray gummy clay to 23 feet. Considerable difficulty was encountered both by the present party and during the Chamber of Commerce investigation, in sinking holes or pits in this neighborhood, on account of the rapid caving of the loose sand of the overburden into the hole.

[99a] Lonsdale, J. T., Geology and ground-water resources of Atascosa and Frio Counties, Tex.: U. S. Geol. Survey Water-Supply Paper 676, pl. 1, 1935.

According to McKnight,

The clays from the pit and from the two test holes sunk on the property show high plasticity, medium hardness, and very satisfactory handling properties except for the high amount of water of plasticity required and the consequent high drying shrinkage. This would suggest the use of dry-press methods for the manufacture of brick. The potteries using this clay probably use it in mixture with other nonplastics to reduce the drying shrinkage.

All samples show low softening points, and in the case of the two sets of samples from locality GS 66 which were given complete tests, the bricklets bloated and cracked as low as cone 06. This would reduce the use of the clay to low-fired wares.

To be worked in large quantities, such as would be required for brick or tile manufacture, would require stripping of 5 to 10 feet of surface material. The location of the deposit is not favorable as regards road connections, but more favorable as regards railroad facilities. On the whole, however, it would appear that its usefulness would be restricted to the small quantity uses which it has already found.

The following tests were made on the samples by the Bureau of Industrial Chemistry:

Tests of clay from Miller farm

Preliminary tests

Depth (feet)	Raw color	Shrinkage (percent) Drying	Shrinkage (percent) Firing	Fired color	Fired condition	UT laboratory No.
Clay pile at pit	Light gray	9.0	4.0	Buff	Very good	23
GS 52						
5-7	Gray	8.5	3.0	do	do	108
7-9	do	7.5	4.5	do	do	109
9-11	do	8.5	4.5	do	do	110
11-12	do	5.0	5.0	Dark buff	Good	111
12-13	Red and gray	5.5	2.0	Red	do	112
GS 66						
8½-10	Light olive	8.5	4.0	Dark buff	Very good	129
10-12	Blue-gray	8.0	3.5	Light red	do	130
12-14	do	8.5	4.0	do	do	131
14-17	Brown	7.5	5.0	Red	do	132
17-20	Blue-gray	8.0	4.0	Buff	do	133
20-23	do	8.5	5.5	Light buff	do	134

Complete tests

Sample number	UT 108-110	UT 130-132	UT 133-134
Dry color	Gray	Blue-gray	Blue-gray.
Hardness	Medium	Soft	Medium.
Plasticity	High	High	High.
Shrinkage water	14.4	14.3	14.6.
Pore water	10.6	9.9	10.6.
Water of plasticity	25.0	24.2	25.2.
Drying shrinkage	28.8	27.5	28.9.
Cone 010:			
Color	Buff	Light red	Flesh.
Condition	Steel hard	Steel hard	Steel hard.
Shrinkage	2.8	2.3	2.9.
Porosity	26.2	21.8	21.7
Cone 08:			
Color	Buff	Light red	Flesh.
Condition	Steel hard	Steel hard	Steel hard.
Shrinkage	5.6	3.1	5.6.
Porosity	23.8	19.8	19.6.

Tests of clay from Miller farm—Continued

Complete tests—Continued

Sample number	UT 108-110	UT 130-132	UT 133-134
Cone 06:			
Color	Buff	Light red	Buff.
Condition	Steel hard	Steel hard	Steel hard.
Shrinkage	8.4	4.0	13.2.
Porosity	19.0	9.4	20.5.
Cone 04:			
Color	Buff	Light red	Buff.
Condition	Steel hard	Cracked	Steel hard.
Shrinkage	9.6	1.3	14.0.
Porosity	15.9	9.9	12.4.
Cone 02:			
Color	Buff	Light red	Buff.
Condition	Steel hard	Bloated	Steel hard.
Shrinkage	12.5	0.4	18.2.
Porosity	9.6	7.0	3.3.
Cone 1:			
Color	Gray-green	Brown	Gray buff.
Condition	Incipient vitrification	Bloated	Bloated, vitrified.
Shrinkage	12.7	−24.1	1.8.
Porosity	4.0	7.0	5.5.
Cone 3:			
Color	Gray-green	Brown	Gray buff.
Condition	Incipient vitrification	Incipient vitrification	Bloated vitrified.
Shrinkage	14.9	−13.4	19.5.
Porosity	5.7	1.9	0.6.
Cone 5:			
Color	Gray-green	Green-brown	Gray buff.
Condition	Vitrified	Bloated vitrified	Vitrified cracks.
Shrinkage	12.5	−19.6	11.3.
Porosity	5.0	6.6	1.9.

The following is the record of a test hole put down at the time of the San Antonio Chamber of Commerce investigation, under the direction of Mr. Lawton.[1] It was probably located near the farm house

[1] San Antonio Chamber of Commerce, op. cit., p. 62.

Tests of clay from Miller farm

Depth	Raw color	Material	On firing to 2,000° F.			On firing to 2,250° F.		
			Color	Shrinkage in 8 inches (inches)	Warping	Color	Shrinkage in 8 inches (inches)	Warping
Ft. in. *Ft. in.*								
0 to 1 8	Dark brown	Sandy	These beds were tested with acid and found to contain lime.					
1 8 to 5 10	Brown and gray	Clay and sand						
5 10 to 7 1	Red and gray	Clay and rock						
7 1 to 8 2	Gray and brown	Clay						
8 2 to 8 6	do	Clay and rock						
8 6 to 11 3	do	Clay	Reddish brown	1	None	Chocolate brown	1 3/16	Slight.
11 3 to 11 8		Clay and soft red rock	Dark reddish brown	1 1/16	do	Reddish brown	1 1/4	Do.

CLAYS IN THE YEGUA FORMATION

General character of the formation.—The Yegua formation lies at the top of the Claiborne group, or higher in the section than the formations above described. It is a nonmarine deposit 600 to 1,000 feet thick, consisting of sands, sandy clays, and clays, with some beds of lignite and bentonite, all in thin irregular lenses.[1a]

In southwestern Texas, in McMullen County and adjacent parts of La Salle and Atascosa Counties, the outcrop of the formation is very broad.[2] Here occur a number of deposits of hard white kaolinlike clays, possibly of volcanic origin. These were briefly examined in the field by the writer, in an effort to determine whether any true kaolins could be found. The two main occurrences are on the Kuykendall and Franklin ranches, in the northern part of McMullen County (pl. 5).

Plummer [2a] states that some of the other clays can be used for brick, tile, and other ceramic purposes, but these were not studied by the writer.

Deposit near Los Angeles.—In a roadside near the village of Los Angeles, La Salle County, between Cotulla and Fowlerton, there is said to be a deposit of kaolinlike clay. This deposit was not visited by the writer, but at Fowlerton he saw some large blocks taken from this place, which were being used to make sidewalks in the school yard.

The material is white, massive, and fairly soft when fresh but hardens on drying and exposure. It has a conchoidal fracture. The following tests were made on it (sample UT 103) by the Bureau of Industrial Chemistry:

Raw color, white (hard); shrinkage on drying, 2.0 percent; on firing 1.5 percent; fired color, cream; fired condition, good.

Deposit on Kuykendall ranch.—On the T. R. Kuykendall ranch, 10 miles northeast of Fowlerton and 7 miles east of Zella siding on the San Antonio, Uvalde & Gulf Railway, there has been some prospecting for kaolin. The main prospect pit is on a low hilltop in the prairie 3 miles southwest of the ranch headquarters. The pit was originally 12 feet deep but had partly caved in at the time of the writer's visit. The rock exposed is cream-colored and soft when fresh but turns white and hard on exposure. Apparently it is of the same general composition from the top to the bottom of the outcrop. The rock is faintly laminated and cross-bedded but breaks conchoidally across the bedding planes. Similar material is found in shallow gullies nearby. It is reported that lignite has been found in a well in the bottom of a broad swale between the prospect pit and the ranch headquarters.

[1a] Compiled from Plummer, F. B., op. cit., pp. 668–674.

[2] Deussen, Alexander, and Dole, R. B. Ground water in La Salle and McMullen Counties, Tex.: U. S. Geol. Survey Water-Supply Paper 375, pl. 8, p. 146, 1916. Lonsdale, J. T., op. cit., pl. 1.

[2a] Plummer, F. B., op cit., pp. 675–677.

The following tests were made on the clay (sample UT 101) by the Bureau of Industrial Chemistry:

Raw color, white (very hard); shrinkage, on drying, 2.0 percent; on firing, 3.0 percent; fired color, cream; fired condition, fair.

Deposit on Franklin ranch.—The Franklin ranch joins the Kuykendall ranch on the northeast. About 10 miles east-northeast of the Kuykendall deposit, 1½ miles east of the Franklin headquarters, and 15 miles south of Christine, there is another similar deposit which has been prospected. This lies on the east side of a small northward flowing tributary of San Miguel Creek, known locally as Live Oak Creek, on the south side of the road from the Franklin headquarters to the Tilden-Christine road.

Several excavations have been made here for 100 feet or so along the creek and have exposed 12 to 15 feet of white hard clay of uniform quality. According to McKnight,

Of the three McMullen County samples, that from the Franklin ranch (UT 102) showed the most favorable color and body on firing. An attempt was accordingly made to improve these properties by washing. A portion of the sample was ground fine and triturated with water to form a smooth paste. This was then suspended in water, a short time allowed for gritty and heavy matter to settle out, and the suspension decanted from the settled matter. The sediment was washed twice with small amounts of water to remove any suspendable matter which it retained, and the combined suspensions then allowed to settle clear. The resulting mud was dried at 105° C., ground and tested. The portion thus recovered amounted to about 80 percent of the weight of the sample taken, about 20 percent of gritty and heavy matter having been removed by washing.

Chemical analyses were made on both the raw and washed samples. The washing is seen to have effected a slight decrease in silica, iron, and alkalies, a slight increase in alumina, and a surprising increase in lime content of the clay. With the exception of the last-named, the changes are not significant, and no great improvement in the burning properties of the clay would be expected in the light of the chemical analyses.

The washed clay showed a considerable increase in plasticity, and because of the probability that the shrinkage, which was high even in the raw clay, would be found to be even higher in the washed material, a mixture of equal weights of the washed clay with potter's flint was used for the complete tests. Good bodies are produced at all temperatures, but the colors obtained are invariably buff and less pleasing than the color of the raw clay.

The following tests (sample UT 102) were made by the Bureau of Industrial Chemistry:

Preliminary tests: Raw color, white (very hard); shrinkage, on drying, 7.0 percent; on firing, 4.5 percent; fired color, cream; fired condition, good.

Complete tests: Dry color, white; hardness, very hard; plasticity, medium to low; shrinkage water, 17.3 percent; pore water, 19.3 percent; water of plasticity, 36.8 percent; drying shrinkage, 30.6 percent.

Cone 010:		Cone 02:	
Color	Light buff.	Color	Light buff.
Condition	Very hard.	Condition	Very hard.
Shrinkage	0.0.	Shrinkage	1.8.
Porosity	41.2.	Porosity	37.0.
Cone 08:		Cone 1:	
Color	Buff.	Color	Light buff.
Condition	Very hard.	Condition	Very hard.
Shrinkage	1.0.	Shrinkage	2.6.
Porosity	34.1.	Porosity	36.5.
Cone 06:		Cone 3:	
Color	Buff.	Color	Light buff.
Condition	Very hard.	Condition	Very hard.
Shrinkage	1.9.	Shrinkage	3.0.
Porosity	35.5.	Porosity	36.8.
Cone 04:		Cone 5:	
Color	Buff.	Color	Light buff.
Condition	Very hard.	Condition	Very hard.
Shrinkage	1.7.	Shrinkage	2.9.
Porosity	35.1.	Porosity	37.2.

Chemical analyses:

	1	2		1	2
SiO_2	73.05	71.15	Na_2O	3.28	1.33
Al_2O_3	9.27	10.68	TiO_2	.0	.0
Fe_2O_3	2.42	1.78	CO_2 and H_2O	6.38	7.94
CaO	2.83	5.66			
MgO	1.85	1.41	Total	100.65	101.03

1. As received.
2. Washed to remove 20 percent of heavy matter.

The following are the results of tests made by the Bureau of Industrial Chemistry on samples submitted in 1922, probably from the same locality ("Franklin ranch, northern McMullen County"). Sample UT 1814 was sent in as kaolin, but the high percentage of fluxes shown by the chemical analysis and the fact that it burns buff shows that it cannot be classed as such. It has extremely high plasticity and high drying shrinkage. The plasticity was so high that as much as 75 percent of nonplastic material could be added and the mixture still be worked. The clay burns to a hard buff body and will make good face brick by either the stiff-mud or the dry-press process. For the stiff-mud process inert grog or sand must be added to reduce the drying shrinkage.[3]

The tests were made on a mixture composed of 40 percent raw clay (sample UT1814) and 60 percent grog.

[3] Potter, A. D., and McKnight, David, op. cit., p. 193.

Tests of clay from Franklin ranch

Cone 010:		Cone 02:	
Color	Light buff.	Color	Light buff.
Hardness	Medium.	Hardness	Medium.
Shrinkage	1.4.	Shrinkage	10.0.
Porosity	39.9.	Porosity	33.8.
Cone 08:		Cone 1:	
Color	Light buff.	Color	Light buff.
Hardness	Medium.	Hardness	Medium.
Shrinkage	3.1.	Shrinkage	12.1.
Porosity	39.1.	Porosity	33.3.
Cone 06:		Cone 3:	
Color	Light buff.	Color	Light buff.
Hardness	Medium.	Hardness	Medium.
Shrinkage	4.8.	Shrinkage	14.8.
Porosity	37.0.	Porosity	32.0.
Cone 04:		Cone 5:	
Color	Light buff.	Color	Light buff.
Hardness	Medium.	Hardness	Hard.
Shrinkage	9.1.	Shrinkage	16.1.
Porosity	34.8.	Porosity	31.0.

SiO_2	75. 45	CaO	2. 19
Al_2O_3	10. 86	H_2O	7. 54
Fe_2O_3	2. 49		
Na_2O and K_2O	2. 82	Total	101. 35

Another sample (UT 1816) tested by the Bureau at the same time and probably from the same source "appears a little more favorable from the standpoint of kaolin" because "lime and alkali contents are somewhat lower than in the former sample," but no burning tests were made on it.

CLAYS IN THE JACKSON FORMATION

General character.—The Jackson formation and its clays are discussed in more detail below, under the heading "Bleaching clays." It is probable that they will always be used chiefly for bleaching, but they have attracted attention in the past because of their possible ceramic use, particularly for the uses to which kaolins are put.

This possibility was investigated by Ries [4] who examined deposits and samples from Lena and Flatonia, Fayette County, and southeast of Gonzales, Gonzales County. Ries' general conclusions are as follows:

Both the weathered and the unweathered clay are of very low plasticity and tensile strength, as well as being quite free from grit. On account of the high amount of water which they absorb and low tensile strength, * * * these clays tend to crack badly in air drying. Chemically they are very similar, so that weathering has apparently produced but little change in the material. Although the percentage of total fluxes is not high, still both of these fused very easily, being melted to a clear glass at cone 27. The presence of limonite shows up very strongly in the dry-press bricklets, which show a number of specks of iron silicate after burning. Although good reports have been circulated from time to time regarding the use of this material for the manufacture of porcelain, it is exceedingly doubtful if it could be used for this purpose, unless deposits of whiter-burning material are found, and even then the very low plasticity and cracking in burning are defects which can only be remedied by the admixture of other materials.

[4] Ries, Heinrich, op. cit., pp. 275-281.

Deposit near Cestahowa.—On the Kaspzik farm, half a mile north of the village of Cestahowa and 5 miles northeast of Falls City, in Karnes County (pl. 5), are exposures of white clay, probably in the lower part of the Jackson formation. These were sampled for their bleaching properties, and the clays are more fully described under that heading, but a sample was also submitted to the Bureau of Industrial Chemistry for a test of its ceramic properties. According to McKnight,

It is hard and white, and of waxy texture as distinguished from the gritty texture of the McMullen County samples [in the Yegua formation; see above]. It could not be considered as representing the same or a related outcrop. The color produced in this sample on firing is not unfavorable, but the inordinate shrinkage and the brittleness produced on drying and firing condemn the clay for ceramic purposes.

The following is the result of a test on sample UT 100 made by the Bureau of Industrial Chemistry:

Raw color, white (hard); shrinkage, on drying, 8.5 percent; on firing, 16.0 percent; fired color, cream; fired condition, brittle.

CLAYS IN PLEISTOCENE AND RECENT DEPOSITS

Pleistocene and Recent deposits cover wide areas in the southern half of Bexar and adjacent counties. The older materials, remnants of former detrital plains or river flood plains, consist in a large part of limestone and chert gravel derived from the higher country back of the Balcones escarpment. In many places they are cemented by caliche. The lower deposits, along the flood plains of the present streams, are finer and consist largely of water-laid clays and silts, with perhaps some loess. In places they are impregnated to a considerable degree by calcium carbonate.

Clays of this sort can be used in the manufacture of brick, and at two localities they have been so used—at Gonzales, Gonzales County, and at Calaveras, Wilson County, near the Bexar County line. The deposit at Calaveras was examined by the writer; for information on that at Gonzales, the reader is referred to Ries' description.[5]

The Calaveras deposit.—Southeast of the village of Calaveras, between the San Antonio & Aransas Pass Railway and the San Antonio River, a quarter of a mile to the south, in the Saspamco quadrangle (pl. 4), is a flat bottom land, into which the river has incised itself about 50 feet. This lies chiefly on the Johns farm and the land immediately to the west. Underlying the flat, as low as the river has cut, are fine-grained brown siltlike calcareous clays. The lower part of the deposit is apparently finer-grained and more calcareous than the upper part. As seen in bricks made from the clay, it burns to a light-buff or cream color.

[5] Ries, Heinrich, op. cit., pp. 201-203.

This is the site of an extensive brick industry which existed in the region from the 1860's until 1915 (see p. 97). The two oldest brickyards, those of Antonio García and the Taylor Co., were operated in the 1870's along the river in the southern part of the present Johns property. That of the Mackey Brick & Tile Co., operated from 1879 to 1915, was nearer the railroad. This company used clay from a deposit west of the Johns farm, and all the clay to a depth of 7 feet was stripped by horse scrapers from the land between the railroad and the river.[6] The clay below a depth of 7 feet was evidently unfavorable for use.

The following test was made by the Bureau of Industrial Chemistry of a sample (UT 107) collected by the writer from the west edge of the Johns farm:

Raw color, brown gray; shrinkage, on drying, 4.5 percent; on firing, −1.0 percent; fired color, light gray; fired condition, good.

The following tests were made by Ries[7] on a sample of material being used by the Mackey Company (R 809):

Water of plasticity	18.7	Plasticity	Low
Air shrinkage	6.7	Slaking power	Fast
Average tensile strength	366	Texture	Gritty
Soluble salts	0.19	Moist color	Dark brown

Firing tests

	Color	Shrinkage (percent)	Absorption (percent)
Cone 05	Whitish buff	0.0	24.32
Cone 03	Grayish buff	1.3	24.04
Cone 1	do	1.3	24.19
Cone 3	Dark buff	1.7	19.98
Cone 5	do	.3	21.14
Cone 9	Slaggy.		

The following chemical analysis of the sample was made for Ries:

SiO_2	37.45	TiO_2	trace
Al_2O_3	7.72	H_2O	2.40
Fe_2O_3	2.02	CO_2	21.80
CaO	27.92		
MgO	.36	Total	99.67
Na_2O+K_2O	.0		

BLEACHING CLAYS

GENERAL FEATURES

Bleaching clays, known locally as "bentonite" and "fuller's earth," are not as well developed in the San Antonio area as the ceramic

[6] These historical notes were furnished to the writer by H. B. Parks and the younger Mr. Johns, the present owner of part of the property.

[7] Ries, Heinrich, op. cit., pp. 199–200.

clays, and they have been produced extensively only in the last 10 or 15 years. One deposit that has been worked near San Antonio lies in the Taylor marl, of Upper Cretaceous age. Most of the deposits, however, are in the Jackson formation of late Eocene age (pl. 5). A few are found in the succeeding Catahoula sandstone. In all the deposits there is a possibility that the clays were derived from volcanic material. Some of them have been found to include relics of volcanic ash and are thus true bentonites. Others, in which no direct evidence of such origin has been found, are here termed bentonitic clays.[8]

PRODUCTION [8a]

One of the earliest worked deposits in the San Antonio area is that 16 miles west of San Antonio, which was operated by the Medina Fuller's Earth Co. Pits were being worked here as early as 1918.[9] The clay was at one time treated at a plant located on the property, but later the plant was moved to the Quintana Road, south of San Antonio. The company was taken over by Bennett & Clark, a San Antonio firm, who in 1931 abandoned the workings in favor of higher-grade deposits that were being opened up in Fayette and Gonzales Counties, about 100 miles east of San Antonio.

Another deposit, 6½ miles south of Gonzales, Gonzales County (pl. 5), was worked as early as 1906. This was formerly operated by the Coen Co., but it has since been taken over by the Earthen Products Co., a Houston firm. Deposits in the vicinity of Riverside, Walker County, have been worked since 1921 by the Continental Oil Co. and its predecessor, the Marland Oil Co., and by the Texas Co., which use the clay in their own oil refineries.

Production methods vary from one deposit to another. In many, stripping of the overburden and digging of the clay are done by power shovel, but in some they are accomplished by blasting, and in others by pick and shovel. Some of the clays are treated either partly or fully at plants near the pits. The material from others is shipped in its raw state to treating plants in the larger towns. Thus both the Continental Oil Co. and the Texas Co. operate treating plants at Riverside, and the Texas Co. at Lena. The Earthen Products Co. and Bennett & Clark, on the other hand, ship their clays by rail to plants in Houston and San Antonio.

Aside from new discoveries made by the Geological Survey party, the following is a list of the bleaching clay deposits known to the writer in central Texas. Some are now being worked, and others are merely promising prospects. The deposits visited by the writer are marked by an asterisk (*):

[8] For definition of term "bentonite", see p. 8.

[8a] For a brief history of bleaching clay production in Texas, see Phillips, D. M., and Phillips, L. V., Production and utilization of Texas bleaching clays: Texas Univ. Bull. 3501, pp. 105–106, 1935.

[9] Sellards, E. H., op. cit., pp. 114–115.

Bleaching clays in central Texas [1]

	County	Location of deposit	Producer, owner, or lessee	Stratigraphic position	Status of operations
*1	Atascosa	Halfway between Campbellton and Christine.	Witherspoon ranch, J. R. Martin, lessee.	Jackson formation	Produced for a time some years ago. To be reopened.
*2	Bexar	16 miles west of San Antonio.	Medina Fuller's Earth Co. (Bennett & Clark, successors).	Near top of Taylor marl (Upper Cretaceous).	Abandoned, 1931.
3	Burleson	5 miles west of Somerville.	Lauderdale	Jackson formation.	Operating in 1931.
*4	Fayette	At Lena siding between West Point and Muldoon.	Texas Co	do	Operating.
*5	do	At Floy siding between Muldoon and Flatonia.	Bennett & Clark	do	Abandoned about 1932.
*6	Gonzales	2.6 miles east and 5.6 miles south from Waelder.	do	do	Operating in 1934.
*7	do	6½ miles south of Gonzales.	Earthen Products Co. (formerly Coen Co.)	do	Do.
8	Grimes	(2)			
9	Jasper	At Browndell, in northeast corner of county.	Houston Oil Co	Catahoula sandstone.	Operating in 1936.
10	do	4 miles west of Rockland, Tyler Co.	Bennett & Clark	do	Do.
11	do	½ mile west of no. 10	Milwhite, Inc	do	Do.
*12	Karnes	Cestahowa, 5 miles northeast of Falls City.	Kaspzik farm, J. R. Martin, lessee.	Jackson formation	Prospect.
*13	do	Conquista Crossing, 4 miles west of Falls City.	(?)	do	Said to have produced years ago.
*14	Walker	¾ mile west of Riverside.	Continental Oil Co	Catahoula sandstone.	Operating.
*15	do	3 miles east of Riverside.	Texas Co	do	Do.

[1] Sources of information (aside from personal observations of the writer) are as follows:
1, 5, 6, 12. Communications from J. R. Martin.
2. Sellards, E. H., op. cit., pp. 114–115. Communications from L. W. Stephenson and J. R. Martin.
3. Broughton, M. N., op. cit., p. 135.
4, 14, 15. Communications from D. M. Phillips.
7. Communications from W. S. Hamilton.
8. Plummer, F. B., op. cit., p. 699; Broughton, M. N., op. cit., p. 135, Communications from D. M. Phillips.
9, 10, 11. Communications from W. G. Hugly, through P. G. Nutting.
13. Deussen, Alexander, op. cit., p. 92 and pl. 2. Communications from H. B. Parks and J. R. Martin.

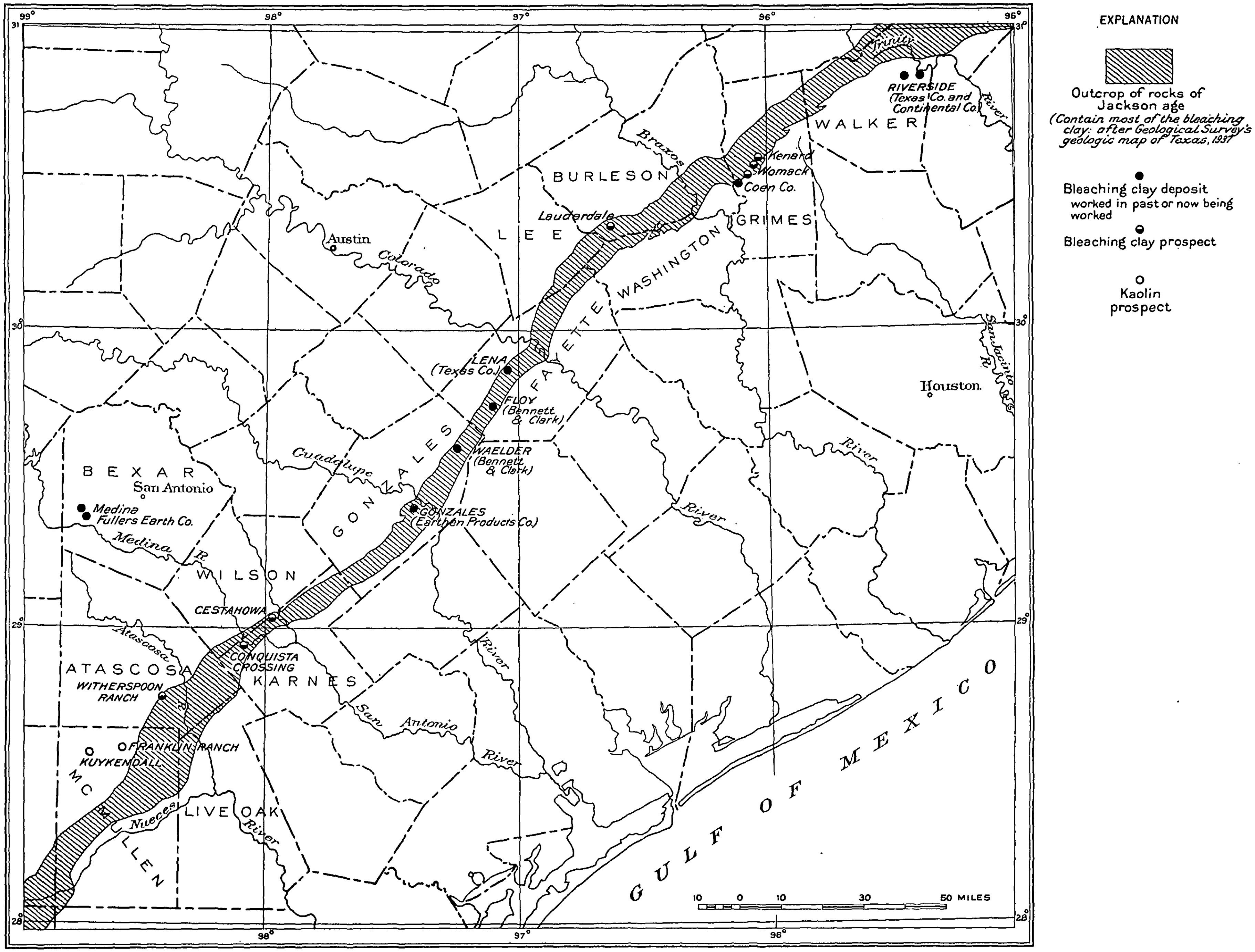
[2] Several localities, whose detailed location and character is not known to the writer, some of which are producing. They are probably all in the Jackson formation. For further information, see under Grimes County, below.

According to tests made by P. G. Nutting in the Geological Survey laboratories, the most promising bleaching clays in Texas in the area near and east of San Antonio are the following, numbered as in the table above.

(1) Clay that is naturally active, but not activable:
Riverside, Walker County (nos. 14 and 15).
Milwhite Inc., Jasper County (no. 11).
Earthen Products Co., Gonzales County (no. 7).
Anacacho limestone, north of Culebra Road near Huebner Creek, Bexar County (discovered by Geological Survey party).

(2) Clay that is almost inactive but is activable:
Lena, Fayette County (no. 4).
Taylor marl, east part of city of San Antonio, Bexar County (discovered by Geological Survey party).

(3) Clay that is both active and highly activable:
Browndell, Jasper County (no. 9).
Bennett & Clark, Jasper County (no. 10).



MAP OF PART OF TEXAS SHOWING OUTCROP OF ROCKS OF JACKSON AGE AND LOCATION OF DEPOSITS OF BLEACHING CLAY AND KAOLIN.

Most of these clays, as well as others sampled from the area, have less bleaching power than those from deposits east of the Mississippi River. Those in group (1) have about the same bleaching power as the Porters Creek clay of Mississippi, Tennessee, Kentucky, and Illinois. The first of group (2) has about half the bleaching power of the best activable clays; that is, when activated it is about as effective as a natural bleaching clay of fair quality. The second has a greater bleaching power and is just under commercial grade for activable clay as it is rated in the deposits east of the Mississippi. The highest bleaching power was found in the clays of group (3). After activation they compare favorably with the best clays from the area east of the Mississippi.

In spite of the low quality of most of the Texas bleaching clays, many of those listed in the table above are being produced commercially. Production is possible because they are closer to markets than those east of the Mississippi River, so that they can be shipped to customers with smaller freight charges. Thus, without added expense, greater quantities of these low-grade clays can be used to obtain the same result that would be obtained with a smaller amount of high-grade clay.

The bleaching clay of the two new deposits discovered by the Geological Survey party, although showing relatively high bleaching power on testing, is probably not of commercial value. Both exposures are in highly faulted areas, so that the outcrops may not be extensive, and the first is in a bed too thin for commercial production. The second at the place studied lies under a thick overburden and in a closely settled; urban area. It is possible, however, that careful prospecting near the two newly discovered localities might reveal tracts underlain by the same clays which would be capable of production.

FIELD WORK

Most of the field work on the bleaching clays was done in Bexar County and nearby parts of adjoining counties, with special emphasis on those in the Taylor marl and other Upper Cretaceous formations. In this work test holes were put down at promising places near or immediately below the Taylor-Navarro contact, as the deposits which had been worked in the past lay at about that horizon. While the party was doing auger work, the writer carried on reconnaissances in unworked areas to determine the location of future test holes. Some field work, resulting in several important discoveries, was done by H. C. Fountain, geologic assistant. Up to the time of the Geological Survey party's work, only two localities aside from those that had produced were known in Bexar County.[10]

[10] Described by C. L. Baker in Sellards, E. H., op. cit., pp. 115-116.

In the later part of the field work an attempt was made to visit as many as possible of the deposits given in the preceding list that were being worked southeast and east of San Antonio. This was considered particularly desirable, in view of the low grade of the bleaching clays in Bexar County. Information on these more distant deposits was obtained through the courtesy of J. R. Martin, of San Antonio; D. M. Phillips, of the Texas Co.; and H. B. Parks, of the Texas Apicultural Experiment Station. As shown by the asterisks in the preceding list, all the known deposits or prospects were visited except those in Jasper, Grimes, and Burleson Counties.

In the reconnaissance work outside Bexar County, it was not possible to make more than very generalized geologic observations. For the stratigraphic position of most of the deposits, the writer is indebted to oil geologists at San Antonio, particularly B. Coleman Renick and Stuart Mossom.

TESTS OF BLEACHING-CLAY SAMPLES

The laboratory methods by which the bleaching power of clays is determined have been described by Nutting.[11] The samples collected by the survey party were all tested by Nutting, and the results are given in the tables which follow. (For explanation of symbols used, see p. 14.)

BLEACHING CLAYS IN ANACACHO LIMESTONE

General character.—The Anacacho formation is a chalky, thick-bedded limestone, typically developed in western Uvalde and eastern Kinney Counties. Toward the east it interfingers with typical Taylor marl, and its top descends progressively lower in the section. In Bexar County it is not much more than 100 feet thick. Toward the top the Anacacho grades, through hard, well-bedded calcareous shales, into the typical Taylor marl.

No beds of bleaching clay are known within the formation itself, but at two closely adjacent localities northwest of San Antonio, bentonitic clay beds have been found by H. C. Fountain on top of the limestones. Their relation to overlying beds is obscure, but they may come at the contact between the Anacacho limestone and the Taylor marl. According to F. B. Plummer,[12] the main bentonitic beds in the Taylor formation east of Austin are in its lower part. As at that place the Anacacho limestone has intergraded entirely into Taylor marl, according to L. W. Stephenson,[13] it may well be that the deposits in Bexar County are correlative with one of these layers.

[11] Nutting, P. G., Technical basis of the bleaching-clay industry: Am. Assoc. Petroleum Geologists Bull., vol. 19, pp. 1050–1052, 1935.

[12] Personal communication, May 1934.

[13] Personal communication.

Deposits near Culebra Road.—The deposits in the top or upper part of the Anacacho limestone lie on the north side of Culebra Road near its crossing over Leon Creek, 5 miles west of the city limits of San Antonio, in the West San Antonio quadrangle (pl. 4). One of these (GS 24) is a few hundred yards north of the road and west of the creek, near the Mackey School. Here shallow gullies expose a ledge 2 feet thick of hard chalky limestones with numerous shells of *Inoceramus*, underlain by soft marls. Above the hard ledge are two exposures of white bentonitic clay overlain by soil and gravel. The maximum thickness of such material exposed is about 3 feet. Typical exposures of Anacacho, with no bentonitic clay, are found south of Culebra Road on Leon Creek and to the west, in cuts on Potranca Creek.

Three-quarters of a mile northeast of this locality, on the east bank of Huebner Creek, a tributary of Leon Creek, the ditches of a side road expose a 3-foot bed of hard nodular chalky limestone (GS 25). This is overlain by white and brown bentonitic clay 3 feet thick, which is capped in turn by 15 feet of terrace gravel. Lower beds are exposed south of the road crossing, on the banks of Huebner Creek, and consist of chalky marls typical of the upper part of the Anacacho. Less than 100 yards upstream all these beds are cut off by a fault, beyond which are massive ledges of Austin chalk. To the east, higher on a hillside, in the ditch of the side road, are some small exposures of brown shale that probably belongs to the Taylor formation.

A search was made for further exposures of the clay bed, but none were found. The localities lie within a single block, cut off by faults to the north and south (pl. 4). In the western and southern parts of this block the older beds of the Anacacho limestone lie at the surface, but the hills to the east are capped by higher beds, probably belonging to the Taylor formation.

The following tests were made by P. G. Nutting on samples collected by the Geological Survey party (see also p. 14):

Tests of clay near Culebra Road

Sample	Raw				Acid-treated				Acid removal			
	G	Y	R	B	G	Y	R	B	Fe	Al	Ca	Off (per-cent)
GS 24	0.4	0.5	0.6	0.7	0.6	0.9	1.1	1.2	Tr.	2	8	60
GS 25a	0.8	1.2	1.2	1.7	1.0	1.5	1.8	2.2	4	4	2	25
GS 25b	0.8	1.1	1.3	1.7	0.8	1.2	1.5	1.9	2	5	3	30

GS 24. Locality a few hundred yards north of Culebra Road and about the same distance west of Leon Creek.
GS 25. Locality ¾ mile northeast of GS 24, road ditch on east bank of Huebner Creek. a, Rock that appeared brown in the field; b, rock that appeared white in the field.

BLEACHING CLAYS IN THE TAYLOR MARL

General character.—The upper several hundred feet of beds of Taylor age in Bexar County are of the facies of the typical Taylor marl. They are chiefly marly, gray to blue-gray clay, for the most part rather thick-bedded, weathering to a pale-brown, yellow, or buff color. Joints and bedding planes are stained by iron, and locally there are secondary masses of crystalline selenite.[14]

The formation in places contains such large fossils as *Exogyra ponderosa*. Most beds also contain abundant Foraminifera, and L. G. Henbest reports that some of the samples collected by the Geological Survey party contain Radiolaria. During the course of the field work, Mr. Fountain studied the Foraminifera, which he washed from samples collected by the party from surface exposures and test holes. His preliminary identifications aided greatly in determining the ages of the beds under investigation. Subsequently representative samples were submitted to L. G. Henbest and J. A. Cushman and are now being studied by them. Their preliminary reports in general confirm the field observations.

The formation is not resistant to erosion and crops out in a low rolling prairie covered by black soil. As it lies only a few miles south of the Balcones escarpment, most of its surface is covered by gravel consisting of limestone and chert washed down from the higher lands behind the escarpment. Most of the gravel deposits were probably laid down on one or more surfaces that have now been dissected, to a depth of 50 or 100 feet, by the present streams. Later washing, and creeping of the soft underlying bedrock, has carried large amounts of gravel from these original positions, so that they now cover not only the hilltops but also the hill slopes and the bottoms of the valleys. Exposures of the Taylor formation are thus usually small. They are found where later erosion or digging has cut through the surface cover of gravel and black soil. Most of the exposures are on the cut banks of streams, in gullies in fields not protected from soil erosion, and in road ditches.

The Taylor formation is overlain, apparently unconformably, by the Navarro formation, of the Upper Cretaceous series. The Navarro consists of shales very much like the Taylor in appearance but less calcareous and more sandy. Near its base are several more or less indurated sandy calcareous layers, which are crowded with the remains of *Exogyra costata, Gryphaea mutabilis*, and other fossils. In places these beds stand as a low scarp or cuesta. The contact between the Taylor and Navarro formations lies in the clays from a few feet to over 10 feet below the oyster bed. Some small megafossils of Navarro

[14] For information on the Taylor marl see Sellards, E. H., op. cit., pp. 44–48; Deussen, Alexander, op. cit., pp. 32–36; Adkins, W. S., Mesozoic systems, in The geology of Texas, vol. 1, Stratigraphy: Texas Univ. Bull. 3232, pp. 463–471, 1933.

type, such as *Crenella sericea*, and many microfossils are found in this interval. At the contact there is usually a slight lithologic change in the clays, and at or slightly above it, at many places in Bexar County, the clays contain scattered black phosphate pebbles from the size of a pea down to microscopic dimensions. The relations between the Taylor and Navarro formations have a bearing on the distribution of bleaching clays in the upper part of the Taylor and are discussed in more detail beyond.

Bentonites and bentonitic clays occur in various parts of the Taylor formation in Bexar County (pl. 4). In the lower part the clays in places have bentonitic properties. The most prominent bed, however, is in the upper part, and consists of a few feet of pure bentonite, overlain by 30 feet or more of strata in which the bentonitic material is mingled with clay and sand. This bed is best developed in an area about 16 miles west of San Antonio and may be absent elsewhere, possibly because of the unconformity at the base of the Navarro formation.

It is probable that the clay in the Taylor formation is a true bentonite of volcanic origin. Altered fragments of undoubted volcanic origin have been determined petrographically by Broughton[15] in the bentonite of upper Taylor age at the Medina Fuller's Earth Co.'s pits.

Volcanic rocks of Upper Cretaceous age are known in nearby areas. Their occurrence has been described and interpreted by Lonsdale.[16] Surface exposures in Travis County and wells drilled in Williamson, Caldwell, Medina, and other counties show altered volcanic rocks, known locally as "serpentine," interbedded in the Upper Cretaceous formations. The greater part are sedimentary rocks composed of volcanic detritus, but some are apparently intrusive; in many places even those of sedimentary origin have the form of thick lenses only a few miles across, thus indicating that their source was immediately adjacent. Some of the "serpentine" bodies are interbedded in the Austin chalk, many lie near the contact between the Austin and Taylor formations, and some, such as that at the Thrall oil field, in Williamson County, lie well within the Taylor formation, or closer to the horizon of the bentonite layers in Bexar County. Lonsdale interprets the "serpentines" of the Upper Cretaceous as having originated from submarine volcanic activity.

It is possible that the bentonitic material in Travis County was transported by marine currents, or carried through the air from the nearby volcanic centers, or it may be that the material was transported from much more distant areas through the air by the wind.

Bentonites and bentonitic clays in the lower part of the Taylor marl.— In some places in Bexar County the clays in the lower part of the

[15] Broughton, M. N., op. cit., p. 138.

[16] Lonsdale, J. T., Igneous rocks of the Balcones fault region of Texas: Texas Univ. Bull. 2744, pp. 110-149 and Plate I, 1927.

Taylor formation appear to be bentonitic, and at one place there is a thin bed of bentonitic clay. All these materials appear to have inferior bleaching powers, but their occurrences are worth noting.

Bentonitic clays were found in the lower part of the formation between Potranca Creek and a north-south secondary road about 2 miles northwest of the old Medina Fuller's Earth Co. pits south of the Castroville Road, or 16 miles west of San Antonio, in the West San Antonio quadrangle (pl. 4 and test holes GS 11, 12, and 13, fig. 15). Along the east side of Potranca Creek in this neighborhood is a cut bank about a quarter of a mile long. At the north end of the cut are hard well-bedded, somewhat sandy and very calcareous clays, which appear to be transitional from the Anacacho limestone into the Taylor. These dip downstream at a low angle and pass beneath slightly laminated well-bedded light-brown, bluish, and gray somewhat sandy clays, with numerous ferruginous seams on the bedding planes. According to H. C. Fountain, the dried material slakes readily in water and on washing yields fine white sand and numerous arenaceous Foraminifera.

A few hundred feet south of these exposures, at a higher stratigraphic level, the clays in the cut bank are softer, have a gray color with light mottlings, and break out in irregular blocks. They appear to be of slightly bentonitic character. About 10 feet above the base of the exposure is a 1-foot bed of very ferruginous bentonitic clay. A test hole put down at the base of the exposure (GS 11) shows that the bentonitic character decreases downward. In the next exposure to the south the dip has reversed to the northwest, and Anacacho limestone has been mapped along the stream a short distance to the south. The structure is thus apparently synclinal.

East of the creek, in a field near a farm house, is a small patch of ground in which *Exogyra costata* is found abundantly, apparently representing an outlier of the basal beds of the Navarro formation. No trace was seen, however, of the bentonitic beds of upper Taylor age, which are well developed a few miles to the southeast. A test hole (GS 13) put down a few hundred yards southwest of this outlier showed clays of rather high bleaching power. (See table below.)

That the beds exposed in this neighborhood are not the same as the main bentonitic beds of upper Taylor age to the southeast is suggested by the following features: (1) Their lower part is only a short distance stratigraphically above the upper part of the Anacacho limestone. (2) Clays with bentonitic properties are irregularly distributed in the section, and this character fades out downward as well as upward, whereas in the upper Taylor bed there is a sharp contact at the base with nonbentonitic clays. (3) According to the driller who put down

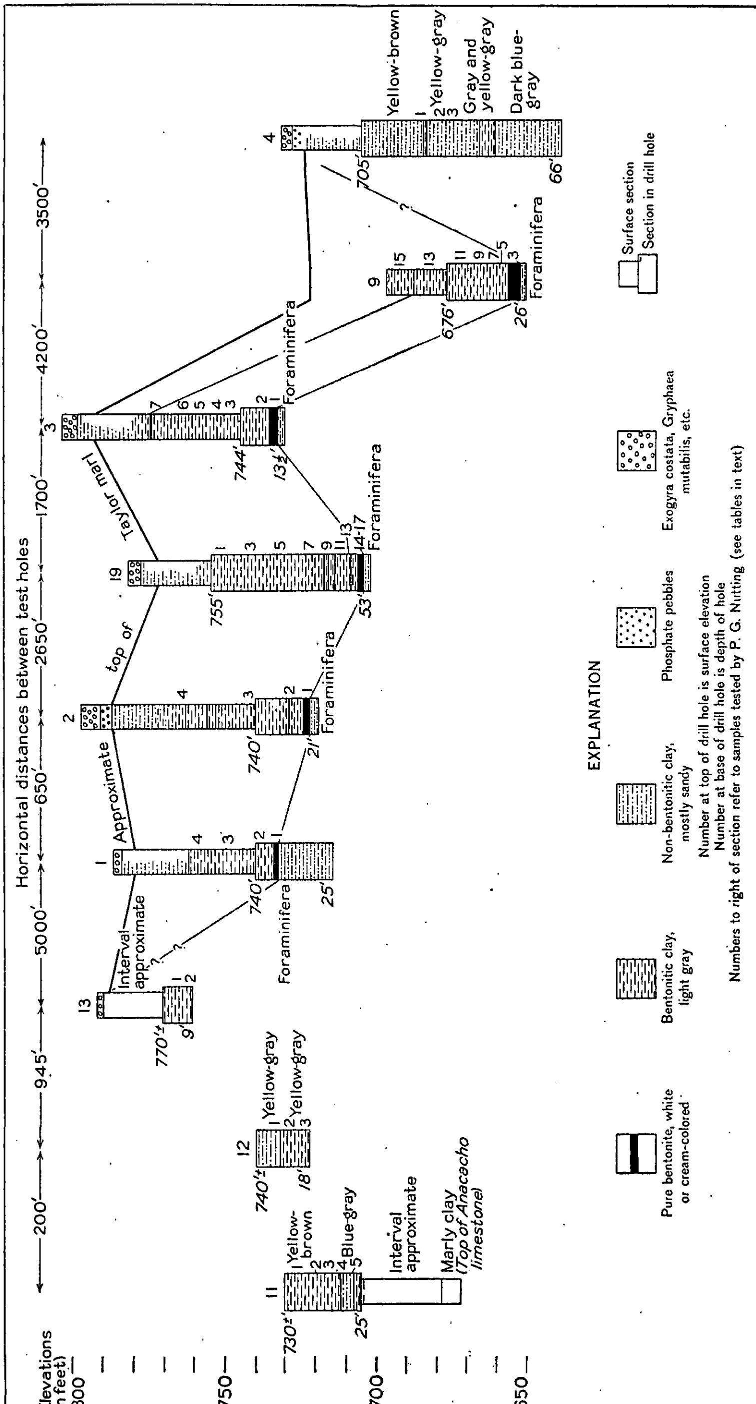


FIGURE 15.—Correlated sections and drill holes in upper part of Taylor marl extending north and south of Medina Fuller's Earth Co. pits west of San Antonio, Tex.

the water well at the fuller's earth pit south of the Castroville Road, there was, on top of the "chalk" (Anacacho?), and many feet below the producing bed, a 30-foot bed of clay, which closely resembled in its properties that which was being mined at this place at the surface.

Similar superposition of the basal Navarro beds on beds in the Taylor believed to be below the main bentonitic clay layers appears 0.8 mile south of the pit of the Medina Fuller's Earth Co. south of the Castroville Road. In a test hole put down at the side of the Cagnon Road at this place (GS 4), which started 20 feet below the *Exogyra costata* zone and went to a depth of 66 feet, no trace of the main bentonitic clay was found (column 4, fig. 15). Some thin layers of bentonitic character were noted in the upper part of the boring at a level below the base of the Navarro, and their bleaching tests are given in the table below.

Some tests were made on clays known to underlie the main bentonitic layer 4½ miles west of the Medina Fuller's Earth Co.'s pits (GS 6), and they were shown to have slight bleaching properties.

A layer of bentonitic clay is also known in the Taylor formation east of San Antonio.[17] This is exposed in the lower part of a cut bank on Saltrillo Creek on the old Seebold farm, 200 feet east of a side road and a quarter of a mile north of the new Seguin Highway, 9½ miles east of the city limits of San Antonio, in the East San Antonio quadrangle (pl. 4). A test hole put down at this place (GS 26) showed that the bed was about 3 feet thick, with some very thin bentonitic layers a few feet below it. Apparently the clay bed is in the middle or lower part of the Taylor formation, for the lithology of the adjacent clays is more like this part of the formation, and a test hole put down a mile to the east, at the intersection of the new Seguin Highway and the Graytown Road, which started near the Taylor-Navarro contact, failed to reach the clay at a depth of 45 feet. According to a water-well driller in this neighborhood, farm wells nearby go through several hundred feet of blue clay, in which, near a depth of 125 feet, are two layers a foot thick of white bentonitic clay, probably the equivalent of the bed exposed on the Seebold farm.

The following tests have been made by P. G. Nutting on samples collected from this part of the formation by the Geological Survey party:

[17] First described by C. L. Baker in Sellards, E. H., op. cit., p. 116.

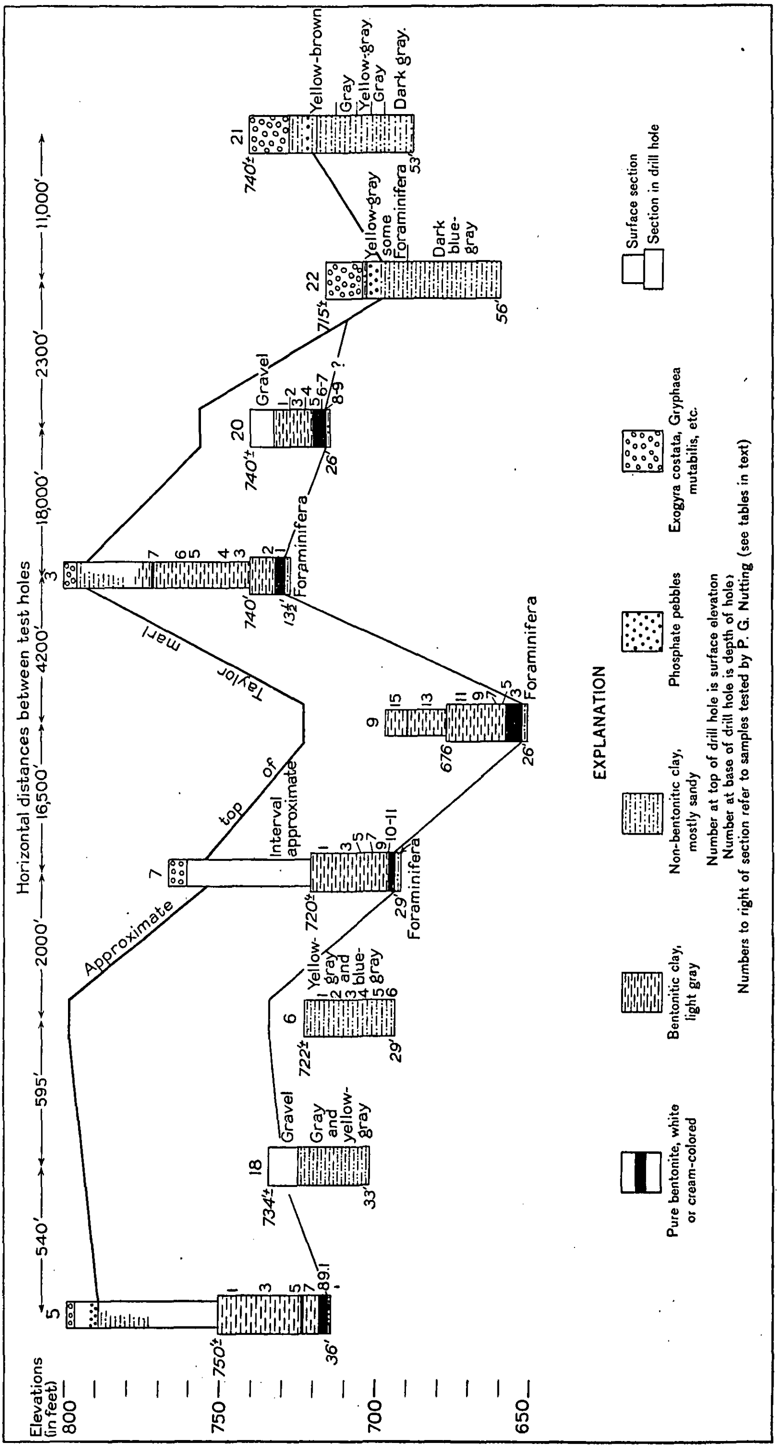


FIGURE 16.—Correlated sections and drill holes in upper part of Taylor marl extending east and west of Medina Fuller's Earth Co. clay pits west of San Antonio, Tex.

Tests of bentonitic clays from lower part of Taylor marl

Locality and sample	Raw				Acid-treated				Acid removal			
	G	Y	R	B	G	Y	R	B	Fe	Al	Ca	Off (percent)
GS 13—1	0.3	0.4	0.5	0.5	1.1	1.7	1.9	2.3	5	3	2	35
2	.3	.4	.4	.4	1.1	1.7	2.0	2.2	5	4	1	30
GS 12—1	.1	.2	.2	.2	.9	1.2	1.3	1.4	4	2	4	25
2	.1	.1	.1	.2	.9	1.1	1.2	1.2	4	3	3	25
3	.2	.3	.3	.3	.6	1.1	1.3	1.5	4	4	2	35
GS 11—1	.4	.4	.5	.5	.6	1.0	1.1	1.2	4	4	2	30
2	.3	.4	.5	.6	.9	1.3	1.5	1.8	4	4	2	30
3	.4	.4	.5	.5	.8	1.1	1.4	1.6	4	4	2	30
4	.3	.4	.4	.4	.9	1.3	1.6	1.8	4	4	2	30
5	.2	.3	.3	.3	.8	1.3	1.5	1.6	4	4	2	25
GS 4—1	.1	.2	.2	.2	.7	1.1	1.2	1.4	4	3	3	40
2	.1	.2	.2	.2	.6	.9	1.1	1.4	5	3	2	35
3	.3	.4	.4	.4	.7	1.0	1.2	1.7	4	4	2	35
GS 6—1	.1	.1	.1	.2	1.0	1.5	1.7	1.9	1	2	7	50
2	.5	.5	.6	.6	1.0	1.7	1.9	2.1	4	3	3	30
3	.4	.4	.5	.5	1.1	1.9	2.1	2.5	4	3	3	30
4	.3	.4	.4	.4	.5	.7	.8	.8	4	2	4	40
5	.5	.5	.5	.5	.9	1.0	1.3	1.4	4	3	3	30
6	.3	.4	.4	.4	.5	1.0	1.2	1.3	4	3	3	40
GS 26—2	.4	.5	.5	.5	.9	1.4	1.7	2.1	5	4	1	25
3	.4	.5	.5	.5	1.0	1.6	1.8	1.9	4	5	1	25

Localities GS 13, 12, and 11 constitute a fairly complete section of the lower part of the Taylor formation as shown in figure 16.

GS 13. 2 miles northwest of Medina Fuller's Earth Co. pit south of Castroville Road, 1½ miles north of Castroville Road, 200 feet west of farm house. Samples at following depths in test hole: 1, 5 feet; 2, 9 feet.

GS 12. Same general area as GS 13; top of bluff on Potranca Creek west of farm house, at a lower stratigraphic horizon. Samples at following depths in test hole: 1, 6 feet; 2, 11 feet; 3, 16 feet.

GS 11. Same general locality as GS 12; base of bluff on Potranca Creek, with top of hole about 13 feet lower stratigraphically than sample 3, hole 12. Samples at following depths in test hole: 1, 4 feet; 2, 9 feet; 3, 14 feet; 4, 19 feet; 5, 24 feet.

GS 4. 0.8 mile south of Medina Fuller's Earth Co. pit south of Castroville Road, in road ditch on Cagnon Road. Samples obtained not far below base of Navarro formation, but seem to be from a horizon in lower part of Taylor formation. Samples at following depths in test hole: 1, 20 feet; 2, 27 feet; 3, 29 feet.

GS 6. 4½ miles west of Medina Fuller's Earth Co. pit south of Castroville Road, at east end of concrete bridge on Castroville Road. From beds known to underlie the main bentonite horizon of the upper Taylor, this being encountered in hole 5, up the hill to the west. Samples at following depths: 1, 5 feet; 2, 9 feet; 3, 14 feet; 4, 19 feet; 5, 24 feet; 6, 29 feet.

GS 26. 9½ miles east of city limits of San Antonio, a quarter of a mile north of new Seguin Highway, in bed of Saltrillo Creek on old Seebold farm. From layer of bentonite in beds probably of lower Taylor age. Samples at following depths: 2, 3–3½ feet; 3, 2–3 feet.

Bentonites and bentonitic clays in upper part of Taylor marl.—The chief occurrence of bentonitic clays in the upper part of the Taylor formation is in the region north and south of the Castroville Road from 7 to 15 miles west of the city limits of San Antonio, in the West San Antonio and Castroville quadrangles (pl. 4). All occurrences in this neighborhood lie within one east-northeastward trending fault block. To the north-northwest of the block the Anacacho limestone is raised to the surface, and to the south-southeast the Midway and Wilcox groups of the Eocene are dropped in.

This is the region that was developed in the past by the Medina Fuller's Earth Co., which has dug two groups of pits, one on the south side of the Castroville Road 10 miles west of the city limits of San Antonio, and the other a mile to the north-northwest, a quarter of a mile west of the Cagnon Road. It is reported that the first operations were at the south pits north of the road, that the pits south of the road were opened later, and that, after the properties were taken over by Bennett & Clark, the northern pit of the group north of the road was opened.[18] The pits have not been operated since 1931.

Natural exposures of the bentonitic clays are not common in the neighborhood, as this part of the Taylor formation appears to be nonresistant to erosion. The two best exposures are (1) in the cut bank of Potranca Creek south of the Castroville Road and 0.7 mile southwest of the pits of the Medina Fuller's Earth Co. south of the Castroville Road (GS 9); here only the upper part of the bentonitic member is exposed, and its base lies 24 feet beneath the surface; (2) in the cut bank of Lucas Creek 4 miles west-northwest of the Medina Fuller's Earth Co. pit south of the Castroville Road, 1 mile north of the Castroville Road, in the Kothmann (formerly Masterson) pasture (GS 8).[19] Here only the lower part of the bentonitic member is exposed.

A more complete artificial exposure may be seen in the southern of the two pits north of the Castroville Road. The following is a section of the sequence, with the record of the test hole (GS 2) drilled in the bottom of the pit added to complete the description of the bentonitic member:

Section in southern pit north of Castroville Road

	Feet
Navarro formation:	
8. More or less indurated sandy calcareous brown ledges, full of *Exogyra costata* and *Gryphaea mutabilis*	6
7. Clay, light-colored, with numerous phosphatic pebbles in lower part and scattered oyster shells toward top. Rests with sharp contact on clays below, which are darker-colored	4
Taylor marl:	
6. Clay, yellowish, becoming slightly bentonitic below	24½
5. Clay, bentonitic, with ferruginous seams at top, and 16½ and 13 feet above base. Extends to base of pit	23
4. Clay, gray, somewhat sandy, very bentonitic, penetrated in test hole	11
3. Bentonite, white or light gray, sandy in upper part, with ferruginous seam at top	5
2. Bentonite, pure, with a few inches of strongly iron-stained bentonite at base	2½
1. Clay, dark gray or brown, non-bentonitic, in part quite sandy, containing numerous Foraminifera. In the test hole in the north pit (GS 1) the thickness penetrated was 17½ feet	3
Interval from base of Navarro to base of bentonite (bed 2)	66

[18] Information from J. R. Martin, of San Antonio.

[19] First described by C. L. Baker in Sellards, E. H., op. cit., p. 116.

Clay localities near Medina Fuller's Earth Co. pits

Locality	Distance from pit south of Castroville Road	Location	Thickness of basal bentonite bed (feet)	Interval from bentonite to base of Navarro formation (feet)
GS 5	4½ miles west	East side of hill on Castroville Road.	2	66+
GS 7	4 miles west	0.3 mile south of Castroville Road.	2	68±
GS 8	4 miles west-northwest	Cut bank on Lucas Creek	3	50±
GS 1	1 mile north-northwest	North fuller's earth pit north of road.	1	52
GS 2	do	South fuller's earth pit north of road.	2¼	66
GS 19	½ mile north	Cagnon Road	2½	75
GS 3		Fuller's earth pits on south side of Castroville Road.	3	72
GS 9	0.7 mile southwest	Cut bank of Potranca Creek	3	(?)
GS 20	3 miles east-northeast	Dwyer Road, just off Castroville Road.	3½	(?)

A similar sequence is found at various places in the neighborhood, the most distant being 4½ miles west and 3 miles east of the Medina Fuller's Earth Co. pits. The localities are listed in the preceding table.

At all these places the base of the bentonitic member is a bed of nearly pure bentonite a few feet thick, which rests with sharp contact on nonbentonitic, fossiliferous clays. The pure bentonite is a soft waxy or soapy rock of white, cream, or pale-greenish color, breaking out in large irregular blocks when dug. When fresh the rock is damp; and when allowed to dry in the sun, specimens lose their waxy appearance, harden, and break along innumerable irregular cracks. When placed in water, the material swells and slakes rapidly to an impalpable powder. The contact between the bentonite and the underlying nonbentonitic clays is everywhere marked by a ferruginous seam a few inches thick. At one place in the cut on Lucas Creek (GS 8) there is, just above the bentonite bed, a lens several feet wide and 6 inches thick of hard white clay that crumbles to a mealy powder; tests show that the lens is calcareous.

The bentonitic clays above the bentonite layer rest with a fairly sharp contact on it, but they have many of its properties. They can be broken out in large irregular blocks, and they crack into small pieces on drying. Their color is a darker gray than that of the layer below, and in places they are mottled with cream-colored spots. Most of them are slightly sandy, and H. C. Fountain has washed some Foraminifera from samples of them collected at the north pit north of the Castroville Road. The bentonitic character fades out upward, and the strata just under the Navarro formation are finely sandy and nonbentonitic.

A sample of the clay from the Medina Fuller's Earth Co. pits has been studied petrographically by Broughton,[20] who states that it—

[20] Broughton, M. N., op. cit., pp. 138–139.

contains more impurities than most of the other specimens studied [from the Tertiary]. The same bentonitic texture is present, however. Many devitrified uncollapsed bubble walls, crescent-shaped masses, and shards of volcanic glass are present. Angular fragments of quartz, tourmaline, calcite, and a greenish-brown mineral resembling amphibole are present. Foraminifera composed of calcite * * * are present. The matrix of this rock is very coarse-textured compared with that of the other specimens studied * * * The clay mineral of the fuller's earth has a high double refraction and an index approximately the same as that from Somerville [1.505].

Specimens collected by the Geological Survey party were tested by P. G. Nutting, who reports:

This series of specimens all appear to be limy bentonitic silts in composition. In a few (as nos. GS 1–3, 1–4, 2–1, 2–3, and 3–7) natural leaching has progressed sufficiently to produce a bleaching power of low-grade fuller's earth type. None of them is sufficiently pure or leached so little as to be of interest as high-powered clays after acid leaching. Sample GS 3–5 is the best, having about two-thirds of the bleaching power, treated, of a first-class bentonite. * * * Most of them are so high in lime as to require nearly twice the acid for activation that typical bentonites do. They do not show sufficient bleaching power to be of commercial interest, unless low quality is overbalanced by low freight charges or other considerations.

The following tables show the results of tests made by Mr. Nutting. In these tables the tests made on the basal bentonite bed are separated from those on the overlying bentonitic clays.

Tests of bentonite near old Medina Fuller's Earth Co. pits:

Locality and sample	Raw				Acid-treated				Acid removal			
	G	Y	R	B	G	Y	R	B	Fe	Al	Ca	Off (percent)
GS 1—1	0.5	0.6	0.7	0.8	0.6	0.8	0.9	1.2	2	7	1	25
GS 2—1	.6	.7	.8	.9	.7	1.0	1.1	1.3	4	4	2	30
GS19—14	.5	.7	.8	.9	1.0	1.3	1.5	1.7	3	4	3	35
15	.3	.4	.5	.7	.6	.9	1.0	1.2	5	4	1	25
16	.3	.4	.4	.5	.5	.8	1.0	1.2	5	4	1	25
17	.3	.4	.5	.5	.9	1.4	1.6	1.9	5	4	1	25
GS 3—1	.4	.5	.6	.8	1.1	1.4	1.6	1.9	4	4	2	30
GS 9—1	.4	.5	.6	.6	.8	1.1	1.3	1.6	8	3	1	0.3
2	.3	.4	.5	.5	.6	.9	1.1	1.4	5	4	1	.2
3	.4	.5	.6	.7	.5	.8	1.0	1.3	3	4	3	.2

GS 1. Northern of two pits of Medina Fuller's Earth Co. 1 mile north of Castroville Road 16 miles west of San Antonio. Sample 1 at depth of 7½ feet in test hole drilled in base of pit.
GS 2. Southern of two pits north of Castroville Road. Sample 1 at depth of 16 to 18 feet in test hole drilled in base of pit.
GS 19. Halfway between group of pits north of Castroville Road and the Castroville Road, in roadside ditch on Cagnon Road. Samples at following depths in test hole: 14, 49 feet; 15, 50 feet; 16, 51 feet; 17, 52 feet.
GS 3. Northern of two pits of Medina Fuller's Earth Co. on south side of Castroville Road 16 miles west of San Antonio. Sample 1 at depth of 11 feet in test hole drilled in base of pit.
GS 9. At cut bank of Potranca Creek south of Castroville Road and 0.7 mile southwest of southern group of pits of Medina Fuller's Earth Co. Samples at following depths in test hole: 1, 24 feet; 2, 23 feet; 3, 22 feet.

Tests of bentonite east and west of old Medina Fuller's Earth Co. pits

Locality and sample	Raw				Acid-treated				Acid removal			
	G	Y	R	B	G	Y	R	B	Fe	Al	Ca	Off (percent)
GS 8—1	0.5	0.7	0.8	0.8	1.0	1.4	1.7	2.0	3	4	3	30
2	.5	.7	.8	.9	1.0	1.4	1.8	2.1	3	4	3	25
GS 7—10	.6	.9	1.1	1.2	1.0	1.4	1.6	1.8	4	3	3	25
11	.5	.7	.8	.9	.9	1.1	1.3	1.6	5	4	1	25
GS 5—8	.6	.7	.7	.7	.7	1.2	1.5	1.8	4	3	3	35
9	.4	.5	.6	.6	.5	1.1	1.2	1.5	5	3	2	30
10	.5	.6	.7	.8	.6	.9	1.1	1.6	3	4	3	35
GS 20—6	.5	.6	.8	.9	.9	1.3	1.5	1.8	4	3	3	40
7	.4	.5	.7	.8	.6	.9	1.1	1.4	4	4	2	40
8	.5	.6	.8	.9	.6	.9	1.0	1.2	4	4	2	30
9	.4	.5	.6	.7	.5	.7	.9	1.1	6	2	2	30

GS 8. 4 miles west-northwest of Medina Fuller's Earth Co. pit south of Castroville Road, 1 mile north of Castroville Road, in cut bank of Lucas Creek, in Kothmann (formerly Masterson) pasture. Surface samples, as follows: 1, base of bentonite bed; 2, 2½ feet above base of bed.

GS 7. 4 miles west of Medina Fuller's Earth Co. pit south of Castroville Road, 0.3 mile south of Castroville Road in bed of small stream east of side road. Samples at following depths in test hole: 10, 26 feet 11, 27 feet.

GS 5. 4½ miles west of Medina Fuller's Earth Co. pit south of Castroville Road, in road ditch of Castroville Road on east slope of hill. Samples at following depths in test hole: 8, 33½ feet; 9, 34 feet; 10, 35 feet.

GS 20. 3½ miles east of Medina Fuller's Earth Co. pit south of Castroville Road, 500 feet south of Castroville Road, in road ditch of Dwyer Road, east of Medio Creek. Samples at following depths in test hole: 6, 21 feet; 7, 22 feet; 8, 23 feet; 9, 24 feet.

Tests of bentonitic clays from upper part of Taylor marl near pits of Medina Fuller's Earth Co.

Locality and sample	Raw				Acid-treated				Acid removal			
	G	Y	R	B	G	Y	R	B	Fe	Al	Ca	Off (percent)
GS 1—2	0.5	0.6	0.8	0.9	0.6	0.8	0.9	1.3	4	3	3	40
3	.6	.7	.8	.9	1.0	1.4	1.6	1.9	4	3	3	40
4	.6	.7	.8	.9	.7	1.0	1.1	1.3	4	3	3	40
GS 2—2	.4	.5	.5	.5	.7	1.0	1.1	1.3	4	4	2	35
3	.6	.7	.8	1.0	.6	1.1	1.4	1.7	4	3	3	40
4	.3	.4	.4	.4	.7	1.0	1.2	1.5	5	3	2	30
GS19—1	.3	.5	.6	.7	.9	1.4	1.6	1.8	3	3	4	45
3	.3	.4	.4	.4	.5	.8	1.0	1.4	4	4	2	30
5	.2	.3	.4	.4	.6	1.0	1.3	1.5	4	4	2	35
7	.6	.7	.8	.9	.7	1.0	1.2	1.5	4	4	2	40
9	.5	.6	.7	.8	.8	1.2	1.5	1.9	4	3	3	40
11	.5	.6	.7	.8	.8	1.2	1.4	1.6	3	3	4	40
13	.4	.5	.6	.7	.8	1.1	1.2	1.3	4	3	3	35
GS 3—2	.5	.6	.7	.7	.8	1.1	1.3	1.5	5	3	2	30
3	.5	.7	.7	.8	1.0	1.4	1.5	1.6	4	4	2	20
4	.5	.6	.7	.7	.9	1.2	1.3	1.6	4	3	3	40
5	.4	.5	.6	.6	1.1	1.5	1.9	2.5	4	4	2	30
6	.4	.5	.6	.7	1.0	1.4	1.7	2.0	5	2	3	40
7	.6	.7	.7	.8	1.0	1.3	1.5	1.9	3	4	3	40
GS 9—5	.4	.5	.8	.9	.6	1.0	1.2	1.3	3	4	3	25
7	.5	.6	.7	.8	.5	.8	1.1	1.5	4	3	3	25
9	.5	.6	.8	.9	.9	1.4	1.6	1.8	3	3	4	25
11	.4	.5	.6	.7	.6	.9	1.2	1.4	2	3	5	30
13	.4	.5	.6	.7	.6	.9	1.0	1.2	4	3	3	30
15	.2	.3	.3	.3	1.0	1.4	1.6	1.8	3	3	4	30

GS1. Northern of two pits of Medina Fuller's Earth Co. 1 mile north of Castroville Road, 16 miles west of San Antonio. Samples at following points: 2, base of pit; 3, 10½ feet above base of pit; 4, 20 feet above base of pit.

GS2. Southern of two pits north of Castroville Road. Samples at following points: 2, 11 to 12 feet in test hole at bottom of pit; 3, 1 foot above top of test hole; 4, 25 feet above top of test hole.

GS19. Halfway between group of pits north of Castroville Road and Castroville Road, in roadside ditch on Cagnon Road. Samples at following depths in test hole: 1, 4 feet; 3, 14 feet; 5, 24 feet; 7, 34 feet; 9, 39 feet 11, 43 feet; 13, 47 feet.

GS3. Northern of two pits of Medina Fuller's Earth Co. south side of Castroville Road 16 miles from San Antonio. Samples at following points: 2, at depth of 9 to 10 feet in test hole; 3, 3 to 4 feet above top of test hole; 4, 8 to 9 feet above; 5, 14 feet above; 6, 20 feet above; 7, 30 feet above.

GS9. At cut bank of Potranca Creek south of Castroville Road and 0.7 mile southwest of southern goup of pits of Medina Fuller's Earth Co. Samples at following points: 5, at depth of 20 feet in test hole; 7, at depth of 16 feet; 9, at depth of 11 feet; 11, at depth of 4 feet; 13, 6 feet above top of test hole; 15, 16 feet above.

Tests of bentonitic clays from upper part of Taylor marl east and west from old pits of Medina Fuller's Earth Co.

Locality and sample	Raw				Acid-treated				Acid removal			
	G	Y	R	B	G	Y	R	B	Fe	Al	Ca	Off (percent)
GS 8—3	0.5	0.7	0.8	0.8	1.0	1.4	1.8	2.2	3	4	3	30
4	.6	.9	1.0	1.1	.9	1.8	2.1	2.4	4	3	3	30
5	.6	.8	.9	1.0	1.1	1.7	2.0	2.5	3	4	5	30
6	.4	.5	.6	.7	.6	1.1	1.3	1.5	3	4	3	30
7	.4	.5	.6	.7	.6	.7	.9	1.1	4	3	3	30
GS 7—1	.4	.4	.5	.5	.6	1.1	1.4	1.5	4	3	3	30
3	.5	.6	.7	.8	.7	1.1	1.5	1.9	4	3	3	30
5	.4	.5	.6	.7	.7	1.3	1.7	1.9	4	3	3	30
7	.6	.8	.9	.9	.8	1.3	1.5	1.7	4	3	3	30
9	.6	.7	.8	.8	.9	1.2	1.4	1.6	4	3	3	30
GS 5—1	.4	.5	.5	.5	.6	1.0	1.2	1.7	4	4	2	35
3	.5	.7	.7	.8	1.2	1.7	2.1	2.2	4	3	3	20
5	.6	.7	.8	.8	1.1	1.5	1.4	1.6	4	2	4	25
7	.4	.5	.6	.6	.7	1.0	1.2	1.4	4	3	3	35
GS 20—1	.6	.7	.8	.8	.6	.8	1.1	1.4	3	2	5	60
2	.6	.7	.8	.9	.6	.9	1.1	1.4	3	2	5	60
3	.4	.5	.6	.6	1.0	1.4	1.6	1.8	3	2	5	60
4	.6	.7	.8	.9	.6	.9	1.1	1.7	3	3	4	50
5	.5	.6	.7	.8	.7	.9	1.2	1.7	3	3	4	50

GS 8. 4 miles west-northwest of Medina Fuller's Earth Co. pit south of Castroville Road, 1 mile north of Castroville Road, in cut bank of Lucas Creek, in Kothmann (formerly Masterson) pasture. Surface samples as follows: 3, 5 feet above base of bentonite bed; 4, 7½ feet above base; 5, 10 feet above base; 6, 12½ feet above base; 7, 15 feet above base.

GS 7. 4 miles west of Medina Fuller's Earth Co. pit south of Castroville Road, 0.3 mile south of Castroville Road, in bed of small stream east of side road. Samples at following depths in test hole: 1, 4 feet; 3, 11 feet; 5, 16 feet; 7, 20 feet; 9, 24 feet.

GS 5. 4½ miles west of Medina Fuller's Earth Co. pit south of Castroville Road—road ditch of Castroville Road on east slope of hill. Samples at following depths in test hole: 1, 4 feet; 3, 14 feet; 5, 24 feet; 7, 32 feet.

GS 20. 3½ miles east of Medina Fuller's Earth Co. pit south of Castroville Road, 500 feet south of Castroville Road, in road ditch of Dwyer Road, east of Medio Creek. Samples at following depths in test hole: 1, 11 feet; 2, 13 feet; 3, 15 feet; 4, 17 feet; 5, 19 feet.

There is another exposure of bentonite in the upper part of the Taylor formation in the eastern part of the city of San Antonio, at a locality discovered by H. C. Fountain. This is in a railroad cut on a spur line leading to Fort Sam Houston, 7 blocks east of New Braunfels Street, between Carson and Jim Streets, in the East San Antonio quadrangle (locality GS 29, pl. 4). The cut is traversed by a fault that brings down the basal beds of the Navarro formation on the south. On the north side of the fault, the upper 25 feet of the cut consists of bentonitic clays, below which is exposed 3 feet of bentonite, and 14 feet more of bentonite is revealed in a test hole drilled at the base of the cut by the Geological Survey party. It is underlain by yellow-brown fine sandy clay with abundant microfossils which, according to H. C. Fountain, are like those in the beds immediately beneath the bentonite west of San Antonio, thus suggesting that these beds belong to the same horizon.

It is possible that this thick layer of bentonite, 17 feet in all, is to be correlated with the layer 2 to 3½ feet thick west of San Antonio;

if so, it would appear that the beds in the eastern part of San Antonio are nearer the source from which the materials came.

The following tests of samples collected by the Geological Survey party were made by P. G. Nutting:

Tests of bentonite in eastern part of city of San Antonio

Locality and sample	Raw				Acid-treated				Acid removal			
	G	Y	R	B	G	Y	R	B	Fe	Al	Ca	Off (percent)
GS29—1	0.2	0.3	0.4	0.4	1.2	1.9	2.1	2.3	4	4	2	30
2	.5	.6	.7	.7	1.2	2.0	2.1	2.2	4	4	2	30
4	.5	.6	.7	.7	1.3	2.3	2.4	2.5	4	3	3	35
5	.3	.4	.4	.4	1.2	1.9	2.0	2.0	3	4	3	35
7	.2	.3	.4	.4	1.2	1.8	1.9	2.0	3	4	3	35
8	.3	.4	.4	.4	.9	1.4	2.0	2.1	3	4	3	30
10	.3	.4	.4	.4	1.1	1.6	1.8	1.9	4	3	3	30
11	.3	.4	.5	.5	1.2	1.7	2.0	2.4	3	4	3	30
12	.5	.6	.7	.7	1.1	1.7	2.0	2.4	4	3	3	20
13	.2	.4	.5	.5	1.0	1.5	1.9	2.1	4	4	2	25

GS29. Eastern part of city of San Antonio, in railroad cut on industrial track to Fort Sam Houston, halfway between overpasses of Jim and Carson Streets. Samples at following depths in test hole: 1, 1 to 2 feet; 2, 2 to 3 feet; 4, 4 to 5 feet; 5, 5 to 5½ feet; 7, 6 to 7 feet; 8, 7 to 8 feet; 10, 9 to 10 feet, 11, 10 to 11 feet; 12, 11 to 12 feet; 13, 12 to 13 feet.

Mr. Nutting comments as follows on these samples: "The thirteen samples of location 29 all respond well to acid treatment and give excellent color separations but are a little too low in bleaching power and too high in lime (requiring much acid) to be of interest." (See also p. 15.)

Localities in which upper bentonitic member of Taylor marl is absent.—At several places west of San Antonio the bentonitic member of the upper Taylor is absent, and the Navarro rests on other strata, which are presumably older. Not only is this true at places removed by a considerable distance from the localities in which the bentonitic member has been found, but also at places within a mile or less of such occurrences. The following table shows places where the upper bentonitic member of the Taylor is known to be absent. (See also figs. 15 and 16.)

Localities 10, 11, 12, and 13 are not much more than a mile from the exposures of the upper bentonitic member at the Medina Fuller's Earth Co. pits north of the Castroville Road (fig. 15). Locality 4 is 0.8 mile from the pit south of the road and 0.6 mile from the excellent exposures of bentonitic clay on Potranca Creek (locality GS9) (fig. 15). Locality 22 is half a mile south of locality 20, at which bentonitic clays and the basal bentonite were found in typical development (fig. 8).

Localities where upper bentonitic member of Taylor marl is absent

No.	Distance from pit south of Castroville Road	Location	Beds that underlie the phosphate pebble zone, or other basal Navarro strata
	10½ miles west	Medina River at Castroville.	Probably Anacacho limestone.
GS 14, 15, 16, 17	10 miles northwest	San Geronimo Creek south of Cliff.	9 feet of yellow-gray sandy clay, possibly bentonitic, underlain by dark blue-gray clay.
GS 10, 11, 12, 13	2 miles northwest	Near Potraca Creek	Gray clays, in part somewhat bentonitic.
GS4	0.8 mile south	Cagnon Road	60 feet of yellow-gray clays, in part sandy, with some bentonitic layers in upper and lower parts. Below, hard blue-gray clay.
GS22	3 miles east	West of Dwyer Road	9 feet of yellow-gray sandy clay, underlain by hard blue-gray clay.
GS21	5¼ miles east-northeast.	Castroville Road west of Leon Creek.	24 feet of yellow-gray sandy clay, in part bentonitic, underlain by hard blue-gray clay.
GS 26, 27	9½ miles east of city limits of San Antonio, near Saltrillo Creek.		25 feet of ferruginous, somewhat sandy clay, underlain by hard blue-gray clay. Thin bentonite bed unknown distance below contact at GS 26.

The bentonitic clays west of San Antonio are commonly supposed by the local people to occur in "pockets"—that is, as lenses or channel fillings. If this were true, the peculiar appearance and disappearance of the bentonitic member would require no particular explanation, but there is evidence to suggest that such is not the case. The lower contact of the bentonite marks a sharp change into nonbentonitic clays below, but it is probably not an irregular or unconformable contact, for the same thin bentonite bed lies above in all places, and the clays beneath are everywhere nonbentonitic, dark gray, sandy, and with abundant microfossils. Irregular deposition is, moreover, unlikely, because the Taylor formation is of marine origin and its fine clastic sediments appear to have been widely distributed before being deposited under water.

The most probable depositional history seems to have been that normal deposition of argillaceous sediments, in an environment which permitted the growth of Foraminifera, was interrupted suddenly by a volcanic outburst that brought into the area a mass of fine ash, later altered to bentonite. A gradual cessation of volcanic activity and the carrying of volcanic detritus more slowly into the region is suggested by the continuance of bentonitic properties in the beds above, but with an increasingly great intermixture upward of clays and sands.

The probable superposition of the Navarro formation on the Anacacho near Castroville and farther west is explained by Stephenson as due partly to the replacement of the Taylor facies westward by that of the Anacacho, but partly to the unconformity at the base of the Navarro. He says, "According to my latest interpretation, the base of the Escondido is resting on the *Diploschiza* zone in the section

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3 miles north of D'Hanis. The unconformity at the base of the Escondido in that area is doubtless the same as the one at the base of the Navarro. The *Diploschiza* zone lies stratigraphically below the bentonite bed."[21]

This relation would seem to account for the absence of the bentonitic member at localities GS 14–17 on San Geronimo Creek south of Cliff. It may also account for its absence at localities GS 10–13, 4, 22, and 21, which are much closer to exposures of the member.

If the unconformity at the base of the Navarro formation is the cause of the relations discussed above, the bentonitic member was probably laid down in upper Taylor time as a continuous sheet over what is now Bexar County and was subsequently, before Navarro time, so eroded that it remains today only as small patches. Its exposures are now so meager that it is not possible to tell much about changes in character in the bed, from which the direction of the source of the materials could be deduced. In its easternmost probable occurrence, however, in the eastern part of the city of San Antonio, the bentonites at the base are much thicker than in the localities west of San Antonio. This suggests that the source may have been to the northeast.

BLEACHING CLAYS IN NAVARRO TO CARRIZO FORMATIONS

Several thin beds of bentonitic clay were noted in the formations succeeding the Taylor. None of them were thick enough to be of commercial interest, but samples were taken for testing, to determine their bleaching properties.

Clay in Navarro formation.—At two localities beds of bentonitic clay less than a foot thick have been noted in beds of Navarro age below the *Exogyra costata* zone. One of these is three-quarters of a mile east of the city limits of San Antonio, at the crossing of Salado Creek by the St. Hedwig Road, in the East San Antonio quadrangle (pl. 4, locality GS 28). The other is on a high cut bank on Long Creek about half a mile west of the Guadalupe River and northeast of McQueeney, in the New Braunfels quadrangle. A sample from locality GS 28 was tested by P. G. Nutting with the following results:

Raw				Acid-treated				Acid removal			
G	Y	R	B	G	Y	R	B	Fe	Al	Ca	Off (percent)
0.4	0.5	0.5	0.5	1.1	1.7	1.8	1.8	3	5	2	30

[21] Stephenson, L. W., letter, June 1934.

Clay in Midway group.—The upper formation of the Midway group, the Wills Point, contains layers of glauconite in its lower part. Some of the best exposures of these in the county are along the west bank of Leon Creek from the Castroville Road south beyond the Quintana Road.[22] At the northernmost exposure, a few yards north of the Castroville Road west of its crossing over Leon Creek in the West San Antonio quadrangle (locality GS 23, pl. 4), H. C. Fountain found a bed of bentonitic clay. The following is a rough section of the beds exposed at this place.

	Feet
4. Coarse terrace gravel at top of bluff	8
3. Greensand, moderately well indurated, in ledges several inches to a foot thick. Less resistant below	4
2. Bentonitic clay, brownish; sandy in upper part	2½
1. Clay, brown, glauconitic, sandy. To base of exposure	17

A sample of the bentonitic clay of bed 2 was tested by P. G. Nutting with the following results:

Raw				Acid-treated				Acid removal			
G	Y	R	B	G	Y	R	B	Fe	Al	Ca	Off (percent)
0.3	0.4	0.4	0.4	1.0	1.6	1.6	1.6	5	4	1	30

Clay in Wilcox group.—During the course of investigating the ceramic clay deposits of the Wilcox group, one sample was collected which seemed to have bentonitic properties. This came from the F. H. Weber property near the Hildebrand Road southeast of San Antonio, from the creek bank at locality GS 47, north of the farm house. It is classed as "detrital kaolinitic clay" by C. S. Ross. Mr. Nutting's test shows the following results:

Raw				Acid-treated				Acid removal			
G	Y	R	B	G	Y	R	B	Fe	Al	Ca	Off (percent)
0.6	0.7	0.8	0.9	0.6	0.9	1.1	1.3	0	8	2	20

Clay in Carrizo sand.—Another sample collected while investigating ceramic clays came from strata considered to be a part of the Carrizo formation. It is from the W. J. Miller farm near the Palo Alto Road, in Atascosa County. It is classed by C. S. Ross as "kaolinitic clay with associated detrital quartz, but no evidence of volcanic ash or bentonitic structure." Mr. Nutting's test shows the following results:

[22] Sellards, E. H., op. cit., pp. 51–53 (described as part of Navarro formation).

Raw				Acid-treated				Acid removal			
G	Y	R	B	G	Y	R	B	Fe	Al	Ca	Off (percent)
0.6	0.7	0.8	0.8	0.9	1.1	1.2	1.3	5	4	1	20

Mr. Nutting comments as follows on the clay from the Weber and Miller localities: "The two samples bleach oil in the same manner, but their acid-soluble constituents are very different."

BLEACHING CLAYS IN THE JACKSON FORMATION

General features.—The Jackson formation is the top unit of the Eocene section in the Texas Coastal Plain. According to Plummer,[23] its strata "consist of marine, brackish-water, near-shore, and continental deposits of light-colored sand, sandy clay, and green tuffaceous clay." He reports its thickness in Gonzales County to be about 900 feet. The outcrops of the group are marked by several ridge-making beds of sandstone, separated by valleys eroded in the softer shales.

The formation has been divided into various members, the history of whose terminology is complex, and has been reviewed by Plummer.[24] The formation is now subdivided by the Texas Bureau of Economic Geology, into three members, based largely on the work of Miss Ellisor, of the Humble Oil Co., who has designated them, in ascending order, Caddell, McElroy, and Whitsett. These subdivisions are based partly on the tracing out of the ridge-making sandstone beds and partly on the various zones of microfossils. Through the help of petroleum geologists who have studied the area, the various bleaching-clay deposits in the group have been placed in these members.

The Jackson formation is overlain unconformably by the Frio clay and in places by the younger Catahoula sandstone.

Material of volcanic origin is common in the Jackson formation. Many of the sandstones are tuffaceous, and the clays contain a noteworthy amount of volcanic ash, mostly now altered to some form of bentonite. Clays of this type are the most important source of bleaching clay, as it is now being produced, in the State of Texas. Producing or prospective territory extends along the outcrop from Grimes County southwestward to Atascosa County.

Deposits in Grimes County.—A number of pits have been opened up for bleaching clay in Grimes County (pl. 5). None of these were visited by the writer, and his information is based on published reports.

23 Plummer, F. B., op. cit., p. 681. For a recent detailed description of the formation in an area extending southwestward from Grimes to Gonzales County, see Renick, B. C., The Jackson group and the Catahoula and Oakville formations in a part of the Texas Gulf Coastal Plain: Texas Univ. Bull. 3619, 1936.

24 Plummer, op. cit., pp. 678–681.

On account of the indefiniteness of most of the descriptions, these pits were not listed in detail in the table on page 150. Moreover, two or more of the deposits listed from different sources of information may actually be the same. The various deposits in the county, when plotted on a geologic map, all seem to lie in the Jackson formation, although some may be in the overlying Catahoula sandstone.

The following table lists the deposits reported from the county:

Clay deposits in Grimes County

Location	Producer, owner, or lessee	Description	Status of operations
1. 8 miles north of Navasota on Bryan Road.	Coen Co.	(?)	Opened in 1934.
2. Williams-Fitzgibbon Survey, near Piedmont Springs.	(?)	Bed 2 feet thick	(?)
3. 2 miles east of Union Hill	(?)	Bed 4 feet thick	(?)
4. Southwest corner of James Tuttle Survey.	(?)	Bed 4 to 5 feet thick	(?)
5. W. P. Zuber Survey	(?)	Bed 4 to 5 feet thick	(?)
6. Follow Anderson-Bedias Road 1.9 miles, Carlos Road 4 miles, farm road 1.5 miles to pit.	Womack	(?)	Operating in 1931.
7. Follow Anderson-Bedias Road 1.9 miles, Carlos Road 3.6 miles, farm road ⅜ mile to pit.	Kenard	(?)	Operating in 1931.

1. Phillips, D. M., personal communication.
2–5. Plummer, F. B., op. cit., p. 699.
6–7. Broughton, M. N., op. cit., p. 135.

Broughton [25] gives the following notes on the petrography of clays from the Kenard pit.

The clay * * * shows crystalline clay minerals of high birefringence intermixed with partially altered fragments of volcanic dust, angular quartz grains, a small amount of zircon, and other detritals. * * * The clay mineral from the Kenard pit has a high double refraction and an index of refraction slightly above 1.5218.

Deposit in Burleson County.—Broughton [26] reports a pit opened for bleaching clay on the Lauderdale farm, 5 miles west of Somerville, in southern Burleson County (pl. 5). This point is definitely within the area of outcrop of the Jackson formation. The pit was not visited by the writer. Broughton gives the following notes on the petrography of the clay:

One specimen of fuller's earth from Lauderdale [farm] is generally referred to as bentonite. Like many * * * bentonites, this material has the property of breaking down rapidly when placed in water. This specimen is less contaminated by detrital materials than most of the other clays under consideration. It also shows more and better relict structures of volcanic dust than do most of the other specimens studied. The clay minerals in this specimen occur in large, easily cleaved crystalline flakes.

Clay from the Lauderdale pit * * * shows crystalline clay minerals of high birefringence intermixed with partially altered fragments of volcanic dust, angular quartz grains, a small amount of zircon, and other detritus * * * [It] contains an abundance of fossil leaves, lignite, and other organic remains.

[25] Broughton, M. N., op. cit., pp. 138–139.
[26] Idem., pp. 137–139.

The clay constituent of the so-called bentonite from Lauderdale has an index of refraction of 1.488. Some flakes of deeper pink run slightly above this figure, while lighter-colored flakes run slightly below.

Lena deposit.—At Lena siding on the San Antonio & Aransas Pass Railway, halfway between West Point and Muldoon, Fayette County, the Texas Co. is mining bleaching clay from beds of Jackson age (pl. 5). The deposit lies in blocks 100, 105, and 87, in the southwestern part of the W. F. Hamilton Survey, about half a mile west of the railroad. According to B. C. Renick,[26a] who has mapped the area in detail, it belongs to the uppermost beds of the Caddell of Miss Ellisor, with sandstones of the overlying McElroy of Miss Ellisor cropping out on the hilltops to the east. Some marine pelecypods have been found in associated sandy beds, and the clays of the deposit contain fossil plants.

The company owns 120 acres, about half of which is considered capable of production.[27] Two large pits have been opened, one of which lies in the western part of the tract, the other in the northern part. The beds being worked are 6 to 11 feet thick, and the overburden is 5 to 14 feet thick.

The deposit is dug by power shovel. When dug, the moisture content is 28 percent. The clay is air-dried for a week by being spread to a thickness of 8 inches in sheds, after which it is kiln-dried at a temperature of 400° to 500° F. These two processes reduce the moisture content to 8 percent. It is then shipped to the company's refinery at Port Arthur, where it is acid-treated and then used in petroleum refining.

As exposed in the pits, the deposit consists of two dominant types of rock—(1) gray earthy and sandy clay, known locally as "bentonite," which occurs in beds 6 inches to 1½ feet thick; (2) brown waxy clay, known locally as "fuller's earth," which occurs in beds a few inches to nearly a foot thick and nearly everywhere contains thin seams and lenses of the gray earthy material and abundant fine fragments of plant leaves and stems. According to Phillips, the second type of material predominates in the clay beds nearby in the county, and the first type is more or less restricted to this deposit.

Associated with these materials are several less important rock types—(3) brown earthy material, similar in texture to No. 1 but of different color, apparently due to fine plant fragments; this type occurs in occasional lenses or beds, in which the clay is darkest at the bottom and lightest at the top; (4) gray brittle clay, known locally as "meerschaum," which occurs in lenses a few inches thick and several

[26a] Renick, B. C., op. cit., pp. 17–23. For notes on fossil plants in the deposit see Parks, H. B., and Kirn, A. J., Old and new fossil plant localities in Bexar County and adjacent areas: Texas Acad. Sci. Trans., vol. 18, p. 14 ("Muldoon locality"), 1936.

[27] Information from D. M. Phillips, manager of the plant, to whom the writer is indebted for much of the other information which follows, as well as for pointing out many of the significant features of the deposit in the field.

feet across. In addition, there are in places fissures filled by sand, flat sheets of crystalline selenite along joints, and on some fracture surfaces coatings of ferruginous material. These last three, particularly the selenite, are considered to be objectionable impurities.

The beds in this deposit dip at an angle of 4°–5° ESE. The deposit is cut by numerous joints, and in a few places there are faults which have offset the beds as much as 4 feet.

The clays from Lena have been examined petrographically by Broughton,[28] who reports as follows:

The clays known as "gray earthy" and "brown earthy material" * * * show many partially altered shards of glass, ghosts of former crystals, partially altered crystals of feldspar, angular quartz grains, some of which have inclusions resembling zircon, and a very fine-grained mineral of bluish tint in transmitted light which may be anatase. Numerous small veinlets composed of crystals of clay minerals much larger than the surrounding groundmass are present. These are suggestive of minute cracks along which solutions that aided in the building of the larger crystals may have passed.

Clays from * * * Lena are characterized by high double refraction. Flakes of mineral from the * * * deposit have an index of refraction slightly under 1.5006, with a few particles running slightly higher. These indices of refraction correspond to the range of indices of refraction of minerals included in the montmorillonite-beidellite group.

Samples of the clay collected by the writer were submitted to Mr. Nutting for study, and he comments as follows (see also p. 150):

All these samples, and those from Riverside as well, appear to be bentonitic clays (Fe:Al:Ca=5:4:1 [see p. 15]), and surprisingly alike, although some are rated as fuller's earth and some as bentonites. In the "bentonite" [type 1, above; sample L–1 in table below] Ross finds with the petrographic microscope no shards of volcanic glass, only sedimentary clay. The samples activate very poorly, giving low water-white bleach and poor coloration. The artificially dried, average sample [L–6, below] is the best, but its bleaching power is scarcely half that of the best pure bentonites.

The following tests were made by Mr. Nutting:

Tests of clay samples from Lena

Sample	Raw				Acid-treated				Acid removal			
	G	Y	R	B	G	Y	R	B	Fe	Al	Ca	Off (percent)
L-1	0.2	0.3	0.3	0.3	0.6	0.7	0.8	0.9	5	4	1	30
L-2	.5	.6	.6	.6	.7	1.1	1.2	1.2	5	4	1	25
L-3	.5	.6	.6	.6	.8	1.1	1.2	1.2	5	4	1	25
L-4	.7	.9	1.0	1.1	.6	.7	.8	.9	5	4	1	20
L-5	.5	.6	.6	.6	.6	.9	1.1	1.2	5	4	1	25
L-6	.5	.6	.6	.6	1.0	1.4	1.5	1.6	5	4	1	25

L–1. Texas Co. pit at Lena, 1-foot bed of "bentonite" type.
L–2. Same, 4-inch bed of "fuller's earth" type.
L–3. Same, "brown earthy" type.
L–4. Same, "meerschaum" type.
L–5. Air-dried average sample of all types mined.
L–6. Kiln-dried average sample.

[28] Broughton, M. N., op. cit., pp. 137, 138–139.

Some clay deposits a short distance east of the railroad at Lena, and east of and higher in the section than the Texas Co. deposit, were studied and tested by Ries [29] for use as ceramic clay, but with unfavorable results. He reports that the material forms lenticular beds in sandstone, with thicknesses on the outcrop of as much as 6 feet, and in a well on the J. Bartlett League of 9 to 11 feet. For description of the ceramic tests the reader is referred to Ries' paper. A sample of clay from the Lytenburg farm, southeast of Lena (R 831), was analyzed chemically for Ries, with the following results:

SiO_2	73.00	K_2O	0.10
Al_2O_3	15.79	TiO_2	.43
Fe_2O_3	.63	MnO_2	Trace
CaO	1.29	H_2O	5.76
MgO	1.53		
Na_2O	.16	Total	98.69

Floy deposit.—Not far south of the Lena deposit, at Floy siding on the same railway line, halfway between Muldoon and Flatonia (pl. 5), is a deposit which has been mined by Bennett & Clark, of San Antonio, for use in cottonseed-oil and other refining. It is said to have been abandoned in 1932 in favor of the deposit near Waelder, because the best material had been mined out.[30] The deposit lies in the western part of the Joseph B. Tatum Survey, and is said by Renick [30a] to occur in the lower part of his Manning formation. The clay of the deposit is similar to that of fuller's earth type at Lena and is slightly waxy, and of pale-brown color.

A sample of the deposit, furnished through the courtesy of J. R. Martin, was tested by P. G. Nutting with the following results:

Raw				Acid-treated				Acid removal			
G	Y	R	B	G	Y	R	B	Fe	Al	Ca	Off (percent)
0.5	0.6	0.7	0.7	1.1	1.6	1.8	2.1	5	4	1	25

According to Nutting,

> This appears to be a bentonitic silt and is very little leached. It activates best to a little better than L–6 (clay from Lena as mixed and dried for shipment by Texas Co.), but still is only 60 percent of the best now being produced, and inferior to that of locality GS 29 (Taylor formation) in San Antonio.

Ries [31] reports a deposit of "kaolin" 3 miles northwest of Flatonia, 1¼ miles from the railroad and 2 miles southwest of the Cistern Road,

[29] Ries, Heinrich, op. cit., pp. 275–277.
[30] Information from J. R. Martin.
[30a] Renick, B. C., op. cit., pp. 32–43; also personal communication, 1934.
[31] Ries, Heinrich, op. cit., p. 275.

in the pasture of the Cockerail farm. Here are 2 to 4 feet of "kaolin" stained with iron, 8 to 12 inches of white "kaolin", and 3 to 4 feet of brown fine-grained clay.

Waelder deposit.—On the J. L. Johnson tract, 2.6 miles east and 5.4 miles south from Waelder, Gonzales County (pl. 5), Bennett & Clark are now mining bleaching clay. The deposit lies in beds of Jackson age.

The clays are being dug on a northeastward sloping hillside in several narrow pits. The workable bed, 3 feet thick, is a waxy gray-brown laminated clay. The overburden, 2 to 10 feet thick, consists of waxy gray brittle clay, somewhat lighter than the workable bed when dry. Beds underlying the workable clays are similar to the overburden. Lower on the hillside, about a quarter of a mile to the north, soft, thinly laminated sands are exposed in badlands and are interbedded with several thin ledges of harder sandstone.

The overburden of the clay is stripped off by power shovel, and the clay is loaded by hand into trucks and hauled to Waelder for shipment to San Antonio, where it is treated at the plant of the company.

Samples collected by the writer at the pits were tested by Mr. Nutting with the following results:

Sample	Raw				Acid-treated				Acid removal			
	G	Y	R	B	G	Y	R	B	Fe	Al	Ca	Off (percent)
Bed being worked	0.7	0.9	1.0	1.1	0.8	1.0	1.2	1.4	5	4	1	25
Overburden	.6	.8	.9	1.0	.6	.7	.8	.9	5	4	1	20

Gonzales deposit.—About 6½ miles south of Gonzales and 1½ miles east of the Yoakum Road, Gonzales County (pl. 5), is a deposit that was worked for many years by the Coen Co., but has recently been taken over by the Earthen Products Co., a Houston concern. The deposit was first opened in 1906 with the hope of producing china clay, a venture that was not particularly successful (see p. 146). Later the possibilities of the use of the clay for bleaching purposes were realized.[32] The deposit is of Jackson age and probably lies in the lower part of the subdivision called McElroy by some Texas geologists.

The locality is in rolling hills immediately south of the flood plain of the Guadalupe River. The following is a generalized section of the strata in the vicinity:

[32] This and other information on the deposit was furnished by W. S. Hamilton, the manager. For notes on fossil plants from the deposit, see Parks, H. B., and Kirn, A. J., op. cit., p. 15 ("Gonzales locality").

	Feet
6. Clay, gray, well-bedded, constituting the overburden of the deposit. It contains fossil leaves, and may be tuffaceous	15–20
5. Mr. Hamilton states that at old workings, a few hundred yards from the present ones, there was at one time a thin bed of volcanic ash exposed	0–1
4. Clay bed now being worked: Bluish or white clay, of opaline appearance when wet, drying to porcelainlike texture. At present workings the bed is 5 feet thick, but thins to the east. In some of the older workings it ran as high as 14 feet	5–14
3. Clay, gray, sandy.	
2. Clay, white, bentonitic, of porcelainlike texture, said by Mr. Hamilton to be of inferior bleaching quality. At present workings it is 1 foot thick, at the old ones nearby 3 feet	1–3
1. Sandstone, white, with some overlying sandy clay. On top of this grew a palm forest, whose stumps are scattered all over the floor of the deposit and project into it. They have the characteristic radiating fibers of palm trunks and roots, but these are now replaced by aragonite and manganese oxide	10

About a mile west of the producing pit is another, on the Oscar Dubois farm, with production from the same bed. It is temporarily abandoned. Here the ground is flatter, and the overburden remains at 5 feet over a wide area. The producing bed (4) is about 4 feet thick and the underclay (2) about 3 feet. North of this pit about 25 feet of the underlying sandstones are well exposed, and one layer of white cross-bedded sandstone contains seams of calcareous marine pelecypod shells.

According to Mr. Hamilton, the producing bed has been traced by drop-auger prospecting for some miles to the northeast and southwest along the strike.

Samples collected by the writer were tested by Mr. Nutting with the following result:

Sample	Raw				Acid-treated				Acid removal			
	G	Y	R	B	G	Y	R	B	Fe	Al	Ca	Off (percent)
G-1	0.9	1.2	1.4	1.8	1.0	1.2	1.4	1.7	Tr	6	4	15
G-1a	------	------	------	------	.4	.5	.7	1.0	Tr	6	4	25
G-2	.4	.5	.6	.8	1.1	1.5	1.8	1.8	4	5	1	25
G-3	.5	.6	.7	.8	1.2	1.5	1.8	2.1	2	5	3	30

G-1. Bleaching clay now being dug by Earthen Products Co. 6½ miles south of Gonzales (bed 4 of section).
G-1a. The same, tested after a long leach.
G-2. From thin layer of bentonitic clay that lies beneath the bed being worked (bed 2 of section).
G-3. From Dubois pit, 1 mile west of pit operated by Earthen Products Co.

Mr. Nutting comments as follows on this material (see also p. 150):

The sample from the pit being worked by the Earthen Products Co. south of Gonzales is a fairly good fuller's earth and is not increased in bleaching power by acid treatment. It is chemically exceedingly tough, so we gave it a longer leach, which halved the bleaching power. The material appears to have been a pure bentonite high in calcium. The underlying bentonite is nearly normal, but a little too much leached to be of commercial interest.

Clays were studied by Ries [33] on the J. F. Harwood farm, 6 to 7 miles southeast of Gonzales and 8 miles distant by road. These are probably closely related to those now being worked. The clay exposed on the property consists of a series of lenslike deposits interstratified with soft sandstone and sand. Two types of clay are found here, one being known as fire clay, and the other as "kaolin." Ceramic tests were made on the clay by Ries with unfavorable results (see above, pp. 146, 175) (R 818, 819, 820). The following chemical analysis was made of the "kaolin," which may approximate the character of the bleaching clay now being produced:

SiO_2	76.00	K_2O	0.58
Al_2O_3	11.36	SiO_2	Trace
Fe_2O_3	.72	H_2O	6.20
CaO	1.96		
MgO	1.58	Total	99.26
Na_2O	.86		

Cestahowa deposit.—On the Kaspzik farm, half a mile north of the village of Cestahowa and 5 miles northeast of Falls City, in Karnes County (pl. 5), white clays, possibly of commercial interest, are exposed in several pits. The upland here is capped by gravel probably laid down by the Cibolo River, which is not far to the east. Beneath are laminated ashlike sandy clays, exposed in several ravines. These are underlain by 4 to 5 feet of white clay, soft and soapy when fresh but hard and porcelainlike when dry. This clay has been explored in a pit about 5 feet deep. Below the clay 10 or 15 feet of thin- to thick-bedded gray sandstone is exposed. It is reported that elsewhere on the same farm another shaft, 35 feet deep, was sunk, all in drab clay.[34] Stuart Mossom suggests that these strata are probably in the lower part of the Jackson formation.

A sample collected by the writer was tested by Mr. Nutting with the following results:

Raw				Acid treated				Acid removal			
G	Y	R	B	G	Y	R	B	Fe	Al	Ca	Off (percent)
0.4	0.6	0.7	0.8	0.6	0.7	0.8	0.9	0	7	3	15

[33] Ries, Henrich, op. cit., pp. 277–281.
[34] Information from J. R. Martin.

Clays at Conquista Crossing.—This locality has been described as follows by Deussen:[35] "At Conquiesta Crossing, on [the] San Antonio River, about 4 miles west of Falls City, Karnes County [pl. 5], the Fayette sandstone shows 20 feet of hard bluish-gray sandstone with silicified wood, 60 feet of brown shale or fuller's earth, 3 feet of lignite, and 1 foot of hard sandstone with silicified wood. The shale dips 2½° N. 80° E." According to Stuart Mossom these beds are at the top of the McElroy member of Texas reports, and contain the *Textularia hockleyensia* zone.

According to H. B. Parks,[36] "during the Civil War an attempt was made to make sugar at Falls City. There still remain the ruins of a sugar mill. The reason that the sugar mill was located there was the presence of fuller's earth, which allowed them to bleach the sugar." J. R. Martin states, however, that the clays of this deposit are of inferior bleaching power, although they might be of use for ceramics. The deposit was examined only briefly by the writer, and no samples were taken.

Deposit on Witherspoon ranch.—On the Witherspoon ranch, on the Peeler Ranch Survey, 6 miles west-northwest of Campbellton and 8 miles east of Christine (pl. 5), are deposits of white clay that have been prospected about 1¼ miles west of the ranch house and south of the Campbellton-Christine road. According to Stuart Mossom, who has mapped the area in detail, the deposit lies in the basal part of the McElroy member of Texas reports, and is overlain by lignitic sandstones and white ashlike sandstones [36a]. A considerable amount of clay was taken out several years ago for bleaching at this place by J. R. Martin, and it is reported that the pits will be reopened.

At this locality there is a pit about 200 feet long and 75 feet wide on a westward-sloping hillside. Beneath an overburden about 3 feet thick, 6 feet of clay is exposed. The deposit consists of white porcelainlike clay with faint bedding planes. A sample obtained by the writer was tested by Mr. Nutting with the following results:

Raw				Acid treated				Acid removal			
G	Y	R	B	G	Y	R	B	Fe	Al	Ca	Off (percent)
0.5	0.7	0.8	0.9	0.5	0.7	0.9	1.1	3	5	2	30

[35] Deussen, Alexander, op. cit., p. 92, pl. 25, *B*.

[36] Letter, June 1934.

[36a] Lonsdale, J. T., Geology and ground-water resources of Atascosa and Frio Counties: U. S. Geol. Survey Water-Supply Paper 676, pl. 1, 1935. For notes on fossil plants from the deposit, see Parks, H. B., and Kirn, A. J., op cit., p. 15 ("Witherspoon locality").

BLEACHING CLAYS IN THE CATAHOULA SANDSTONE

General features of the formation.—According to Plummer [37] the Catahoula formation, which lies higher in the section than the Jackson formation and in places rests on it unconformably, "is a series of continental sands, clays, and pyroclastics, interbedded with fluviatile sediments. The upper portion of the Catahoula formation in east Texas is characterized by beds of volcanic ash, fuller's earth, and tuffaceous clays * * * resembling closely clays and tuffs in the Fant member of the Catahoula tuff beds in south Texas. The lower portion is characterized by beds of coarse cross-bedded sandstone, in places cemented with white porcelaneous opaline silica." The Catahoula formation is classed as lower Miocene(?) by the Geological Survey.

The volcanic material in the Catahoula in the southwestern part of the Texas Coastal Plain has been studied by Bailey,[38] and he suggests that at least a part of it came from centers of eruption nearby. Lonsdale, moreover, has presented evidence that intrusions in Uvalde County and elsewhere at the inner margin of the Coastal Plain are of Tertiary age.[39]

Despite the high content of volcanic detritus in the Catahoula formation, not only in southwestern Texas but farther northeast, there is but little production of bleaching clay from it. The only producing areas known to the writer are in Jasper and Walker Counties.

Deposits in Jasper County.—None of the deposits in Jasper County were visited by the writer, but notes on three of them have been obtained by P. G. Nutting from W. G. Hugly, of the Houston Oil Co.

One pit is in the old town site of Browndell, in section 171, Houston & Texas Central Railroad, S. C. Ferris Survey, and is the property of the Houston Oil Co. For some years the clay from this place was sold to Bennett & Clark, who dried and ground it at Nacogdoches and marketed it under the name of Nacogdoches fuller's earth. The deposit covers 46 acres and has a maximum thickness of 22 feet. It contains dark-green clay, containing white gypsiferous specks.

Another pit is 4 miles west of Rockland, Tyler County, in the southwest part of the Blount Survey, Abstract 73. It is the property of the Houston Oil Co. and is operated by Bennett & Clark. It contains bluish-gray clay with brown seams. The third pit is 3,500 feet west of the second, on the Harrelson tract of the J. C. Everett Survey. It is operated by Max B. Miller for Milwhite, Inc. The clay at this place is light bluish gray.

[37] Plummer, F. B., op. cit., pp. 720, 717.

[38] Bailey, T. L., The Gueydan, a new middle Tertiary formation from the southwestern Coastal Plain of Texas: Texas Univ. Bull. 2645, 1927.

[39] Lonsdale, J. T., op. cit., pp. 44–46.

Samples sent in by Mr. Hugly were tested by Nutting with the following results:

Results of tests of samples of clay from Jasper County

Sample	Raw				Acid-treated			
	G	Y	R	B	G	Y	R	B
1	0.8	0.9	1.0	1.1	1.0	2.2	2.6	3.2
2	1.0	1.1	1.2	1.3	1.2	2.2	2.3	2.6
3	1.1	1.6	1.7	1.9	.6	1.1	1.3	1.5

1. Houston Oil Co. pit, at Browndell.
2. Bennett & Clark pit, 4 miles west of Rockland.
3. Milwhite pit, 3,500 feet west of no. 2.

Mr. Nutting comments as follows on these tests (see also p. 150):

Sample no. 1 belongs to that rather rare class of montmorillonite clays which bleach untreated like a fuller's earth, yet which are highly activable by acid treatment. While it is now selling at a low price as crude fuller's earth, it could be sold for a much higher price if it were treated.

Riverside deposits.—The two deposits being worked in Walker County are near Riverside, 9 miles north of Huntsville (pl. 5). One, belonging to the Continental Oil Co. and originally opened by its predecessor, the Marland Oil Co., is located three-fourths of a mile west of the village. The other, belonging to the Texas Co., is located 3 miles east of it.

The following is a generalized section of the beds exposed in the neighborhood [40]:

	Feet
6. Sandstones, mostly thin-bedded, but with some quartzitic lenses, passing up into massive ledges which were at one time quarried east of Riverside by the railroad company.	
5. Upper fuller's earth bed, mined at Texas and Continental deposits	6–16
4. Barren beds, mostly sandy clays; some sandstone	3–12
3. Middle fuller's earth bed, mined at Continental deposit	6–8
2. Barren beds, sandy clays and sandstones	30–50
1. Lower fuller's earth bed, not now being mined by either company, penetrated by shafts and wells	8–16
Barren beds below.	

At the Texas Co.'s deposit the bed being worked is 6 to 16 feet thick and is overlain by 5 to 9 feet of overburden. The deposit is lenticular, with a flat floor that rises gently from the southeast to the northwest and an upper surface that comes up over the thicker parts of the deposit. A pit 1,100 feet long and 600 feet wide has been excavated, which near the center is constricted because of a local thinning of the deposit.

[40] Based in part on the writer's observations, but in part on information from D. M. Phillips, manager of the Texas Co.'s plant. Much other information from Mr. Phillips is given in later paragraphs.

In the thicker part of the deposit the workable bed consists of waxy gray clay, known locally as "fuller's earth," which breaks out in large blocks but which shows some bedding laminations. In the thinner parts of the deposit the clay is similar but is marked by closely set light and dark laminations. On weathering, it breaks up into small grains and hence is known locally as "buckshot clay." These different properties of breaking have some effect on the milling of the clay, but according to Mr. Phillips the bleaching power is the same.

The overburden of the deposit consists of black soil and ashlike sandstone, the latter in places containing the quartzitic layers noted in member 6 of the section, which must be removed by blasting. Beneath the deposit is a 3-foot bed of hard ashlike clay, flecked with mineral grains and containing small pyrite nodules. Below this is another fuller's earth bed 6 to 8 feet thick, which is not being worked at present. As the pit lies near the Trinity River, the water level commonly lies near the base of the present workings, so that the lower bed could probably not be easily dug at this place.

The overburden is removed, and the clay dug by power shovel. The clay is loaded onto cars of a narrow-gage railway and hauled 3 miles west-southwest to the plant on the railway. When dug it has a moisture content of 25 to 28 percent. At the plant it is ground, air-dried, and then kiln-dried, so that the moisture content is reduced 5 percent. It is then sorted into various sizes and shipped in tank cars to the company's refinery at Port Arthur, where it is used directly, without acid treatment.

At the Continental deposit both the middle and upper fuller's earth beds are being worked. The middle bed here is 5 feet thick and is overlain by 9 to 12 feet of barren hard sandy ashlike clay, on top of which is the upper bed, 6 feet thick. This is overlain by 6 feet of hard ashlike sandstone, which constitutes the overburden. These beds are similar to those in the Texas Co.'s deposit but are drier, harder, and blockier, perhaps because the deposit lies farther above the groundwater surface. Both beds are laminated by closely set dark and light bands, in a manner suggestive of varves. The top surface of the upper bed is ripple-marked. At the time of the writer's visit a westward-dipping slickensided fault plane was visible in the lower bed.

The clays at the Continental pit are removed by blasting and are loaded by hand on trucks, to be hauled to the company's mill at Riverside. After treating, they are shipped to the company's refinery at Ponca City, Okla.

Clays from Riverside have been examined petrographically by Broughton,[41] who reports as follows:

[41] Broughton, M. N., op. cit., pp. 137-138.

Fuller's earths from the two pits at Riverside were very similar [to those from Lena]. Numerous shards of volcanic glass, devitrified bubble walls, and long, thin fragments of crystalline material suggestive of crystalline clay minerals formed in situ are present. Small veinlets of relatively large crystals cut the otherwise very fine-grained groundmass. Several ghosts of former crystals are preserved in the fine-grained material, the particles being somewhat coarser in the area occupied by the crystal.

Clays from Riverside * * * are characterized by high double refraction. The mean index of refraction of the Riverside clay is close to 1.523 and seems to vary within comparatively narrow limits on different flakes of material. Some flakes from the same specimen have a slightly higher index of refraction.

Samples collected by the writer were submitted to Mr. Nutting for study. He comments as follows on the material (see also p. 150):

All these samples appear to be bentonitic silts (Fe:Al:Ca=5:4:1) and surprisingly alike. The overburden and underburden (R–3 and R–4) of the Texas Co. pit have as good bleaching power, untreated, as any of the series. Ross finds with the petrographic microscope in R–2 no bentonitic shards of volcanic glass, only sedimentary clay.

The following are the results of Mr. Nutting's tests on the samples:

Sample	Oil bleach raw				Acid-treated				Acid removal			
	G	Y	R	B	G	Y	R	B	Fe	Al	Ca	Off (percent)
R-1	0.5	0.7	0.8	1.0	0.6	0.8	1.0	1.3	5	4	1	25
R-2	.6	.8	.9	1.0	.6	.9	1.0	1.2	4	5	1	25
R-3	.6	.7	.7	.7	.6	.8	.9	1.0	5	4	1	25
R-4	.6	.9	1.1	1.2	.6.	.8	.9	1.0	5	4	1	20
R-5	.6	.8	.9	1.1	.7	.9	1.1	1.5	5	4	1	25
R-6	.6	.8	.9	1.0	.5	.7	.8	1.1	5	4	1	20

R-1. Texas Co. pit east of Riverside; fuller's earth from thick part of deposit.
R-2. Same from thin part of deposit, locally known as "buckshot clay".
R-3. Same; overburden above worked part of deposit.
R-4. Same; clay beneath worked part of deposit.
R-5. Continental Oil Co. pit west of Riverside, lower of two beds that are worked.
R-6. Same, upper of two beds that are worked.

CERAMIC CLAYS OF MORRIS COUNTY, TEXAS

GENERAL RELATIONS

Several days were spent in a reconnaisance of northern Morris County. This county lies in the northeastern part of the State, about 48 miles by road southwest of Texarkana. It consists of rolling to hilly wooded surfaces at an altitude of about 400 feet, with alluvial bottoms and uplands of sandy and sandy clay soils. Pine, gum, and a variety of oak trees are found. The county is well adapted to diversified farming, and has clay, lignite, and iron ore resources.[42]

The surface rocks of the county are various Tertiary formations, which dip to the south. In the northern part of the county, south nearly to the St. Louis Southwestern Railway, the Wilcox group crops out and has prospective clay and lignite resources. This is

[42] Texas Almanac, p. 349, Dallas, 1933.

overlain by the red clays of the Reklaw member of the Mount Selman of the Claiborne group and the Queen City sand member of the Mount Selman, which crop out over much of the southern part of the county. Near Daingerfield and elsewhere in the southeastern part of the county outliers of the Weches greensand member of the Mount Selman formation cap steep-sided hills and contain considerable amounts of iron ore.

At the present time no clays are being dug in Morris County and no potteries or brickyards are in operation. At Mount Pleasant, Titus County, 16 miles west of Omaha, Morris County, is Hogue's pottery, which produces glazed churns, pots, and other heavy ware from clays of the Wilcox group dug a few miles away.

STRATIGRAPHY

The most promising area for clay resources in the county is in the outcrop of the Wilcox group north of the St. Louis Southwestern Railway, in the northern part of the county. Clays from the Wilcox are used extensively for ceramic purposes in other parts of Texas.

The relations and sequence in the group are well displayed along the new public road (State Highway 11) that runs north from Omaha across the Sulphur River to Dekalb (fig. 17). For 2.7 miles north from Omaha the road crosses a rolling upland with outcrops of vermilion-red clays and sandy clays of the Reklaw member of the Mount Selman formation. In places erosion has cut valleys that penetrate the underlying rocks, which appear to be chiefly white clays, as at a point 1.5 miles north of Omaha on the highway and at points 2 miles southwest and 1 mile west of Omaha.

At a distance of 2.7 miles north of Omaha the highway descends a pronounced escarpment (locality A, fig. 17). At this point the red sandy, glauconitic Reklaw rests with sharp contact on white or pale-buff clays. The clays are rather well laminated, in part of waxy and in part of earthy texture, with a certain amount of sand in some of the beds. These come at the level at which the Carrizo sand, well developed to the southwest in Texas, is to be expected, but the predominance of clay at this horizon leads the writer to believe that in this county the Reklaw has overlapped directly onto the Wilcox deposits.

In the lower hills to the north are underlying beds. The white clays below the Reklaw appear to be about 25 feet thick and are underlain by cross-bedded, very thinly laminated gray sands, with considerable carbonaceous matter along the laminae. Successive exposures show very irregularly bedded lenticular sands, sandy clays, and thin beds of pure clay. At a point 3 miles north of Omaha a road cut exposes a 1½-foot bed of impure lignite. These strata seem definitely to belong to the Wilcox group.

Cuts to the north of the lignite exposure, from 3 to 8 miles north of Omaha, and across the valley of White Oak Creek, expose only sandy strata, most of which weather to a light-red soil. Thus a cut on the

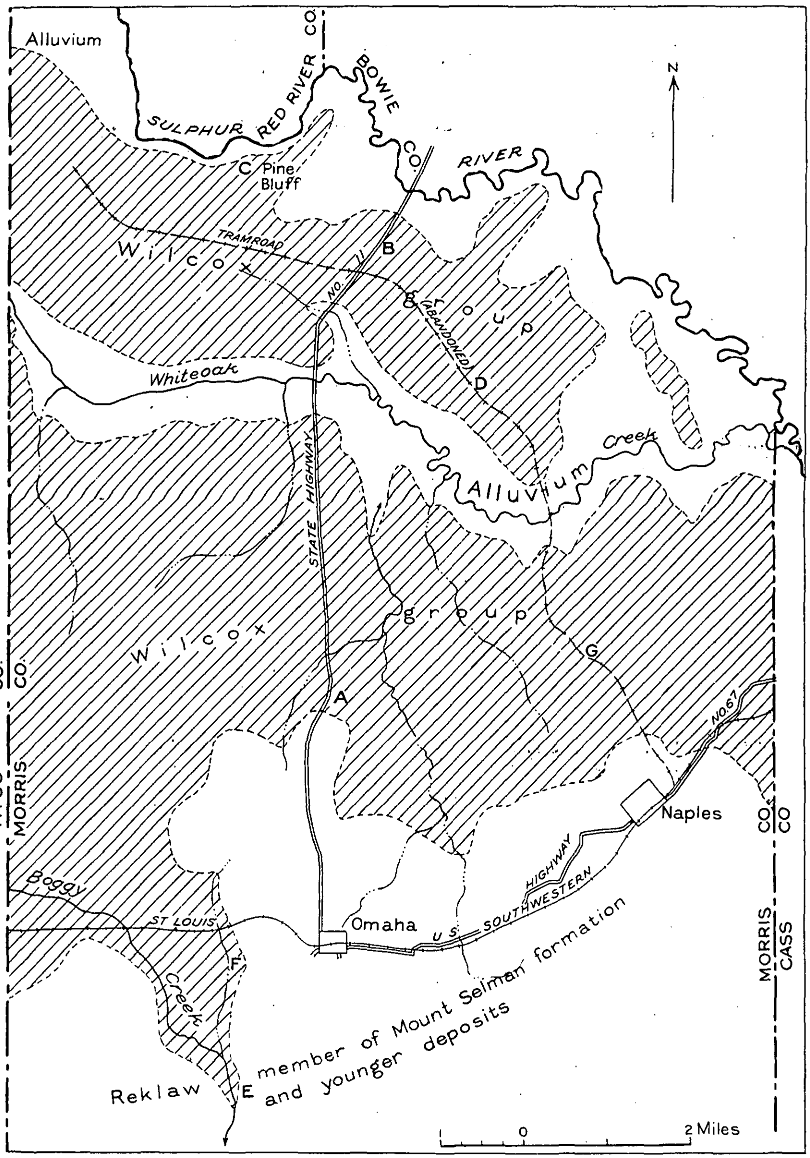

FIGURE 17.—Geologic sketch map of northern part of Morris County, Tex., showing localities from which samples of ceramic clay were obtained.

south edge of the valley of White Oak Creek, 5.1 miles from Omaha, showed slightly indurated, rather coarse-grained brown sandstone in flat slabby beds, with no clays whatever.

Near the Sulphur River, however, clays appear again in the exposures, and at a cut 8¾ miles north of Omaha (locality B, fig. 17), there is 8 feet of gray and white slightly sandy clay.

These observations suggest that there are two main clay horizons in the Wilcox group of Morris County, one in its lower part, exposed near the Sulphur River, and the other in the upper part, near Naples and Omaha on the St. Louis Southwestern Railway.

CERAMIC CLAY POSSIBILITIES

Clays in lower part of Wilcox group.—The cut on highway 11, 8¾ miles north of Omaha near the Sulphur River (locality B, fig. 17), exposes about 8 feet of clays. The clays are whitish or gray, slightly sandy, and very sticky when wet. Even on freshly exposed surfaces the clay has swelled and slipped in a manner suggestive of bentonite. It may be that the clay contains some bentonitic material.

At Pine Bluff, on the Sulphur River, 2 miles west of the crossing of Highway 11 over the stream (locality C, fig. 17), some clays are exposed. At the old iron bridge which crosses the river at this point, about 4 feet of very sandy gray clay, stained by limonite, is exposed near the edge of the river bottom. This clay is overlain by 5 feet of purer gray clay, and this in turn by reddish sand to the top of the hill. Mr. J. R. Martin reports that at a steeper bluff, a few hundred yards to the west, not visited by the writer, there is 20 feet or more of dark-brown and dark-gray clay.

On an old tram line, about 2 miles southeast of its intersection with Highway 11 (locality D, fig. 17) a cut 8 feet high exposes gray sandy clay, which weathers into small hard pellets and is much stained by iron. This is overlain by reddish residual sandy soil. The clay does not look very promising and very probably belongs to the supposed middle sandy beds of the Wilcox group.

Clays in upper part of Wilcox group.—The upper clays, some of whose exposures have been noted in the section on stratigraphy, appear to be widely distributed immediately below the Reklaw member of the Mount Selman formation.

In addition to the exposures on Highway 11, two exposures were studied southwest of Omaha. One of these is 2 miles southwest of Omaha, in a road cut just east of the crossing of a secondary road over Big Boggy Creek (locality E, fig. 17). Here 15 feet of beds are exposed, with a thin layer of hard sandstone in the center of the cut. Below the sandstone are gray waxy clays and dark-gray fat clays; above are ashen-white, finely sandy clays. The other exposure is 1¼ miles due west of Omaha, in a road ditch just east of the crossing of a secondary road over Lick Creek, a tributary of Big Boggy Creek (locality F, fig. 17). Here are ashen-white, finely sandy clays similar to those at locality E. A few wagon loads of clay has been dug at this place and is reported by the local people to have been used for ceramic purposes.

Another exposure, probably in the upper part of the Wilcox group, lies about 2 miles north-northwest of Naples (locality G, fig. 17). The writer's attention was directed to it by L. W. Stephenson. It lies east of the road leading north from Naples, in the cut of an old tram road. At this place 20 feet of beds are exposed, in the following sequence:

	Feet
4. Clay, brownish, sandy, at top of cut, in part reworked	12
3. Ironstone seam	¼
2. Clay, waxy, drab, laminated	4
1. Clay, lignitic, waxy, with some light and dark bands	4

According to L. W. Stephenson's notes, this is underlain by a 6-inch bed of impure lignite, which may have been covered by slump at the time of the writer's visit.

About 300 feet west of the road, in another cut on the tram road at a lower altitude, are beds which appear to be on a downward continuation of the preceding section. Lignitic clay like bed 1 crops out at the top of the cut, beneath which are banded gray clays, some very sandy and some relatively pure, with flecks of carbonaceous material throughout. These do not look as promising as the clays in the first cut. Underlying the sandy clays is a 2-foot layer of hard quartzitic sandstone.

Pottery at Mount Pleasant.—In the western part of the town of Mount Pleasant, 16 miles from Omaha, and in Titus, the next county west from Morris, is Hogue's pottery, which makes glazed churns, pots, bowls, dishes, and other heavy ware. The clay is obtained from two places in Titus County, both of which are probably in the Wilcox group: One of these is at Green Hill, 6 miles to the north, where a sandy clay is obtained. The other is near Winfield, 7 miles to the west, which yields gray waxy clay.

Tests by Bureau of Industrial Chemistry.—The samples from Morris County collected by the writer were submitted to the Bureau of Industrial Chemistry. McKnight makes the following comments on the samples and the results of the tests:

Four samples of clay from Morris County were submitted for ceramic tests, along with two samples of clays now in use in the adjoining Titus County. The last two are found to burn to much lighter color than those obtained from any of the Morris County samples.

Of the Morris County samples, UT 147 shows an excessive drying shrinkage and does not burn to a good body, though the color is good for brick, and better bodies might be produced at higher temperatures. The use of the clay would be limited, however, to brick, and the dry-press method of forming would probably have to be used.

The two samples from adjacent clay beds, taken 2 miles northwest of Naples (UT 145 and 146), show favorable properties, although the upper white clay shrinks somewhat too much both on drying and firing. The lower lignitic clay was given a complete test which showed it to vitrify at a rather low point (incipient at cone 02 and complete at cone 1). The vitrified properties are not favorable, so that the use of the clay would have to be limited to common brick and to cheap pottery fired at such low temperatures as to avoid even incipient vitrification.

Sample UT 148 was also given a complete test. It burns to a hard buff body at low temperatures. It would make common brick if not fired above cone 08, since above this point the shrinkage begins to increase steadily until vitrification occurs at cone 5. The vitrified body seems fairly good, and there might be a chance of making vitrified ware of the clay.

In the case of none of the above samples is there any data furnished as to extent of the deposits, so that it is impossible to give any opinion as to the commercial value of the clays.

The following tests were made on the samples:

Tests of clays from Morris and Titus Counties

Preliminary tests

Location	Raw color	Shrinkage (percent)		Fired color	Fired condition	UT laboratory no.
		Drying	Firing			
Cut on old tram road 2 miles northwest of Naples: lower lignitic part.	Dark gray	7.5	3.0	Light red	Very good	145
Same: white clay in upper part of the cut.	Gray	8.5	5.5	do	do	146
Cut on Highway 11, ¾ mile south of Sulphur River.	do	10.0	2.0	do	Fair	147
2 miles southwest of Omaha, east side of Boggy Creek.	Light gray	4.5	2.0	Pink	Very good	148
Pit at Winfield, Titus County (used by Hogue Pottery).	Gray	6.5	1.5	Cream	do	149
Green Hill, 6 miles north of Mount Pleasant (used by Hogue Pottery).	Light gray	4.5	2.5	Near white	Good	150

Complete tests

	UT 145	UT 148
Dry color	Dark gray	Light gray.
Hardness	Soft	Soft.
Plasticity	High	High.
Shrinkage water	12.1	9.2.
Pore water	15.6	15.7.
Water of plasticity	27.7	24.9.
Drying shrinkage	23.5	18.4.
Cone 010:		
Color	Buff	Light buff.
Condition	Very hard	Hard.
Shrinkage	−0.6	−0.8.
Porosity	32.0	32.3.
Cone 08:		
Color	Buff	Light buff.
Condition	Very hard	Hard.
Shrinkage	−0.6	0.5.
Porosity	30.8	31.6.
Cone 06:		
Color	Darker buff	Buff.
Condition	Steel hard	Steel hard.
Shrinkage	12.7	8.8.
Porosity	19.2	26.9.
Cone 04:		
Color	Dark buff	Buff.
Condition	Steel hard	Steel hard.
Shrinkage	8.0	3.0.
Porosity	22.7	30.0.
Cone 02:		
Color	Dark buff	Buff.
Condition	Incipient vitrification	Steel hard.
Shrinkage	25.4	17.0.
Porosity	9.7	19.3.

Tests of clays from Morris and Titus Counties—Continued

Complete tests—Continued

	UT 145	UT 148
Cone 1:		
Color	Chocolate brown	Darker buff.
Condition	Vitrified	Steel hard.
Shrinkage	29.0	23.1.
Porosity	1.2	12.7.
Cone 3:		
Color	Chocolate brown	Dark buff.
Condition	Vitrified	Steel hard.
Shrinkage	30.8	26.3.
Porosity	1.4	9.9.
Cone 5:		
Color	Green	Gray green.
Condition	Vitrified, bloated	Vitrified.
Shrinkage	−1.1	29.1.
Porosity	1.8	2.0.

Chemical analysis of sample UT 148

SiO_2	67.25	K_2O	1.03
Al_2O_3	15.55	TiO_2	1.31
Fe_2O_3	3.25	CO_2 and H_2O	6.29
CaO	2.09		
MgO	0.25	Total	100.40
Na_2O	3.38		

Chapter 5.—SOME BLEACHING AND CERAMIC CLAYS IN WESTERN TENNESSEE AND POSSIBLE BLEACHING CLAYS IN CALLOWAY COUNTY, KENTUCKY

By M. N. Bramlette

INTRODUCTION

Summary.—The Porters Creek clay is being mined and utilized as a natural bleaching clay, or fuller's earth, at Olmstead, Ill. The Geological Survey, as part of a Public Works project, has collected samples of the same formation at regular intervals throughout the section exposed at two localities in western Tennessee and at one locality in an adjacent part of Kentucky. Laboratory tests indicate that much of the clay near Pinson, in Madison County, Tenn., is as efficient for mineral oil bleaching as that mined in southern Illinois, and that only the uppermost part of the clay in the hill northeast of Huntingdon, Tenn., is equally good. Very large tonnages are easily accessible at both of these localities. The Porters Creek clay from Calloway County, Ky., was less efficient in these tests, though of quality nearly equal to that from Olmstead.

Some prospecting of ceramic clays in western Tennessee was done, in an effort to gain an idea of the future reserves of the high-grade ball clays that are being mined in this region. As the known ball-clay deposits are commonly overlain by poor-grade sandy clays of the wad and sagger type, some of the sandy clays that crop out in the region were tested by auger boring. The results indicate that these sandy-clay outcrops are not generally underlain by good ball clays, though some ball clays of possible value were encountered in such places. However, the clay lenses are so numerous in the Holly Springs sand of this region that comparatively few could be tested in this project, and it seems very probable that additional deposits of high-grade ball clays will be found when a diminishing supply from the large deposits already known results in more intensive prospecting.

Field examinations.—The field exploration was under the supervision of the writer. J. Basil Preston was in immediate charge of the prospecting in Tennessee, with two assistants, and A. C. Munyan, with two assistants, was briefly engaged in the work in Kentucky. Because of the scanty exposures in most of the area investigated, borings were necessary to determine the thickness and extent of the clay deposits and to sample them properly. A 3-inch hand auger was used, with enough 4-foot joints of ¾-inch pipe attached to reach depths of 25 to 30 feet.

Acknowledgments.—Much preliminary information on the field occurrence of clays in the Holly Springs sand was kindly supplied by the Tennessee Division of Geology, through Mr. G. I. Whitlatch, and information on the western Kentucky area was available through the former State geologist, Prof. A. C. McFarlan, from an unpublished manuscript on the geology of the Jackson Purchase area by J. K. Roberts and R. P. Meacham. The conditions and prospects in western Kentucky made it appear inadvisable to devote much prospecting to that area.

L. W. Stephenson, chief of the Coastal Plain section of the Geological Survey, accompanied the writer in a 2 weeks' preliminary reconnaissance of the general region, and this aid was most useful to the subsequent work.

The tests of samples of bleaching clay were all made in the laboratory of the Geological Survey under the direction of P. G. Nutting, whose methods are described on pp. 13–15.

The ceramic tests on all samples were made by Prof. T. N. McVay at the laboratories of the School of Chemistry, Metallurgy, and Ceramics of the University of Alabama, at Tuscaloosa, Ala., who has supplied the statement about the tests given on pp. 16–19.

PORTERS CREEK CLAY AS A SOURCE OF BLEACHING MATERIAL

OCCURRENCE AND CHARACTER

The Porters Creek clay of the Midway group (lower Eocene) extends as a continuous and mappable unit across western Tennessee and into adjacent states, as indicated in a general way on figure 18. In Tennessee it is rather more sandy and micaceous than in some other regions, and there are some lenticular beds of sandstone in the formation, particularly in the uppermost and basal parts; some of these sands are greensands with abundant glauconite. The formation as a whole is a distinctive clay dark gray in fresh exposures but weathering light buff or dove-colored and finally nearly white. The fracture is characteristically hackly to conchoidal. The formation is marine, and in Alabama the writer found in it good foraminiferal faunas which, according to L. G. Henbest, of the United States Geological Survey, are of Midway age. This substantiated the age relations previously determined from the small fauna of larger fossils and from stratigraphic relations.

The formation shows some faulting in western Tennessee, with displacements of as much as 30 feet, and the relations to overlying beds suggest that the faulting is of Quaternary age. Sandstone dikes are of common occurrence in the formation generally and range in thickness from a fraction of an inch to a few inches, but a few are several feet thick. These sandstone dikes consist of a very micaceous sand that is similar to the sandstone beds in the basal part of the formation.

The dikes are generally without obvious vertical displacement, but may have formed coincident with the faulting. A satisfactory determination of the thickness of the formation is difficult to obtain, but it would seem to be between 100 and 200 feet, probably nearer 200 feet, in most of the region.

The formation shows some rather distinctive features that are probably a result of its composition. The clay has a relatively high ratio of silica to alumina, as indicated by the following analyses of this clay from Olmstead, Ill., as reported by Grim:[43]

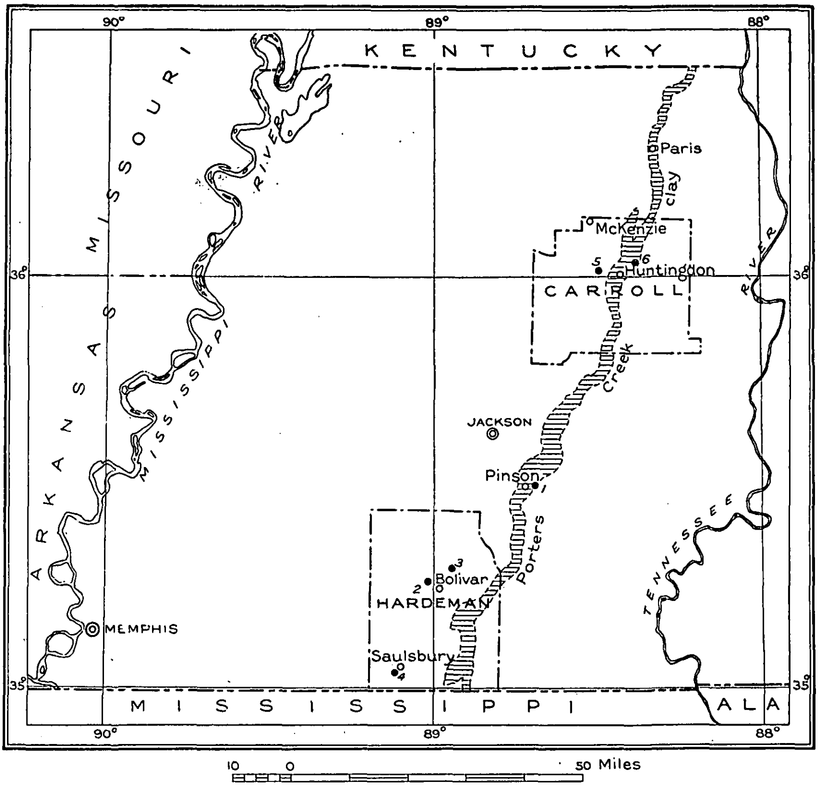

FIGURE 18.—Index map of western Tennessee, showing distribution of Porters Creek clay and areas tested. Localities 1 and 6, bleaching clay; 2–5 ceramic clay.

Analysis of clay from Sinclair pit, Olmstead, Ill.

[Analyses of purified clay fractions made by O. W. Rees, associate chemist, Illinois Geol. Survey]

	Top	Middle	Bottom		Top	Middle	Bottom
SiO_2	61.70	55.42	58.82	K_2O	.98	1.41	1.34
Al_2O_3	13.11	15.61	15.12	H_2O-	5.36	6.35	4.65
Fe_2O_3	2.67	3.55	3.24	H_2O+	10.71	14.28	12.52
FeO	1.96	.20	.73	TiO_2	.23	.46	.44
MgO	1.67	1.46	1.98	P_2O_5	.52	.26	.37
CaO	.85	.94	.55				
Na_2O	.28	Trace	.06		100.04	99.94	99.82

[43] Grim, R. E., Petrography of the fuller's earth deposits, Olmstead, Ill.: Illinois Geol. Survey Rept. Inv. 26, 1933.

The chemical composition is not unlike that of a bentonitic clay, though the silica content is high even for such clays and reflects the presence of free silica as quartz. A recent article by Allen[44] indicates that in Missouri this clay deposit is largely composed of montmorillonite and may be derived from the alteration of volcanic ash. The earlier work of Grim on the same formation in Illinois indicated that the clay was composed of montmorillonite, though his work did not lead him to conclude that it was necessarily derived from volcanic ash. From field and microscopic examinations, the formation in Tennessee appears to consist dominantly of ordinary plastic clay and silt, with a lesser and somewhat doubtful proportion of admixed bentonitic clay.

As a result of its composition and physical character, this clay shows bleaching properties, but of varying degree at different localities and at different stratigraphic horizons. Some of it shows little or no improvement of bleaching power with activation by acid treatment, as is characteristic of a true fuller's earth, and other samples of low natural bleaching power show some improvement with such acid treatment, but none of the Porters Creek clay samples show sufficient improvement with processing to place them in a class with some of the best bentonites as activable bleaching clay. At Olmstead, in southern Illinois, this formation is being mined by the Sinclair Oil Co. and the Standard Oil Co. of Indiana. It has not proved an ideal bleaching clay, but is efficient enough to be of commercial importance because of the large quantity available and its accessibility. A preliminary paper by Whitlatch[45] indicates that in western Tennessee this formation has bleaching properties of possible economic importance.

SAMPLED AREAS, TENNESSEE AND KENTUCKY

The general location of the section sampled three-quarters of a mile northeast of Pinson, Tenn., is shown on figure 18, together with the sampled section at location no. 6 northeast of Huntingdon, Tenn. Figure 19 presents details at the Pinson locality. The samples of Porters Creek clay were taken from the exposures on the southeast side of the road, at 5-foot intervals, from a sample in drill hole 1 up the hill to sample T-18, near the top and about 300 feet northwest of drill hole 2. This series of samples represents regular intervals of the formation from its top down an indeterminate distance into the lower part. Another series of samples was taken at 5- to 10-foot intervals from the outcrops in a hill on Highway 70, 3 miles northeast of Huntingdon, from exposures along a side road running northward up the hill. This series of samples, including those from a drill hole near the base of the hill, represents regular intervals from the base of the Porters Creek

[44] Allen, V. T., Petrography and origin of fuller's earth, southeastern Missouri: Econ. Geology, vol. 29, no. 6, pp. 590–598, 1934.

[45] Whitlach, G. I., Bleaching-earth prospects in Tennessee: Ceramic Age, vol. 24, no. 2, pp. 37–40, 1934.

formation up to an indeterminate position in the upper part. The two sets of samples thus include material at intervals through the entire thickness of the formation and overlap to some extent. No map of the locality northeast of Huntingdon is presented, because the tabulation of bleach tests indicates that except for the uppermost sample the formation here is less efficient as a bleaching clay than the material near Pinson.

The series of samples from a line of bore holes including the entire thickness of the formation, about 1 mile north of Murray, Calloway

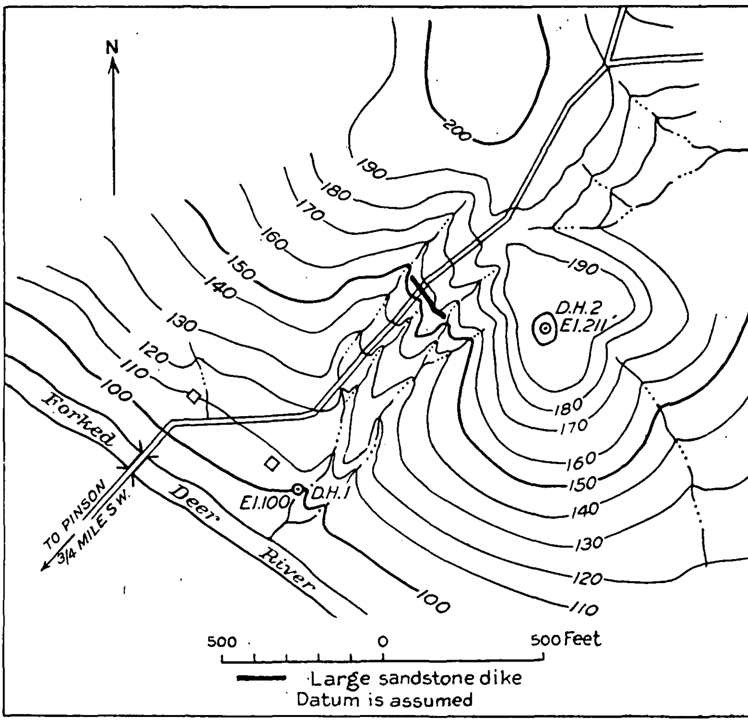

FIGURE 19.—Map showing hill of Porters Creek clay on Luster farm, near Pinson, Madison County, Tenn., and location of test holes. (By J. B. Preston.)

County, Ky., shows in the following tabulation that they are not of as good quality as the clay near Pinson, Tenn.

RESULTS OF BLEACHING TESTS

In the following tables the results of bleaching tests on a sample of the best of the Porters Creek clay from the Sinclair pit at Olmstead, Ill., are presented for comparison, together with data on two well-known fuller's earths from Macon, Ga., and Quincy, Fla. A sample of bentonite produced by the Filtrol Co. at Chambers, Ariz., is also included to indicate the results of the bleaching tests on one of the activable clays.

Tests on samples of Porters Creek clay from Walter Luster farm, ¾ mile northeast of Pinson, Madison County, Tenn.

Sample	Raw				Acid-treated				Acid removal			
	G	Y	R	B	G	Y	R	B	Fe	Al	Ca	Off (percent)
T-1	0.6	0.8	1.0	1.2	1.0	1.3	1.4	1.5	6	4	Tr.	25
T-2	.5	.7	.9	1.1	.9	1.1	1.2	1.3	6	4	Tr.	25
T-3	.7	.9	1.0	1.1	1.0	1.3	1.5	1.6	6	4	Tr.	25
T-4	.9	1.1	1.3	1.4	.8	.9	1.0	1.5	6	4	Tr.	25
T-5	.6	.9	1.0	1.1	.9	1.2	1.3	1.5	6	4	Tr.	25
T-6	.6	.7	.8	.9	1.0	1.3	1.4	1.5	6	4	Tr.	25
T-7	.5	.6	.7	.9	.8	1.0	1.2	1.3	6	4	Tr.	25
T-8	.7	.9	1.0	1.2	1.0	1.3	1.5	1.6	6	4	Tr.	25
T-9	.6	.8	1.0	1.2	.8	1.0	1.2	1.3	6	4	Tr.	25
T-10	.7	.9	1.0	1.1	.9	1.3	1.4	1.5	6	4	Tr.	25
T-11	.7	.8	.9	1.0	1.0	1.4	1.5	1.7	6	4	Tr.	25
T-12	.6	.9	1.0	1.1	1.0	1.4	1.5	1.6	6	4	Tr.	25
T-13	.9	1.0	1.1	1.2	.7	1.1	1.2	1.3	6	4	Tr.	25
T-14	.8	1.0	1.1	1.2	1.0	1.3	1.4	1.6	6	4	Tr.	25
T-15	1.0	1.2	1.3	1.3	.8	1.3	1.5	1.7	6	4	Tr.	25
T-16	.6	.8	1.0	1.1	.7	1.1	1.2	1.3	6	4	Tr.	25
T-17	.9	1.1	1.2	1.2	.6	.9	1.1	1.2	7	3	Tr.	30
T-18	.5	.6	.6	.7	1.1	1.5	1.6	1.6	5	4	Tr.	30

Sample T-1 from depth of 16½ feet in drill hole 1; samples T-2 to T-18, outcrop samples from the base of the exposed section near hole 1, at 5-foot intervals to the top of the formation. (See fig. 19.)

Bleaching tests of lower part of Porters Creek clay from hill 3 miles northeast of Huntingdon, Carroll Co., Tenn. (Location 6, Fig. 16)

	Raw				Acid-treated				Acid removal			
	G	Y	R	B	G	Y	R	B	Fe	Al	Ca	Off (percent)
T-21	0.6	0.7	0.7	0.7	0.7	0.9	1.0	1.1	4	6	Tr.	15
T-22	.5	.6	.6	.7	.7	.9	1.0	1.1	5	5	Tr.	20
T-23	.4	.5	.5	.5	.7	.9	1.0	1.1	6	4	Tr.	25
T-24	.7	.8	.8	.9	.7	1.1	1.3	1.4	7	3	Tr.	30
T-25	.6	.7	.8	.9	.6	.9	1.1	1.2	6	4	Tr.	25
T-26	.7	.9	.9	1.0	.6	.7	.8	.9	6	4	Tr.	25
T-27	.7	.8	.9	1.0	.7	1.0	1.1	1.2	7	3	Tr.	20
T-28	.6	.7	.8	.9	.6	.7	.7	.8	6	4	Tr.	20
T-29	.6	.8	.9	1.0	.6	.8	.9	1.0	6	4	Tr.	15
T-30	.7	.8	.9	.9	.7	.8	.9	1.0	7	3	Tr.	25
T-31	1.1	1.3	1.4	1.4	.8	.9	1.0	1.1	6	4	Tr.	25
Porters Creek clay, Olmstead, Ill.	.7	.9	1.0	1.1	.6	.7	.8	1.2	5	4	1	25
Floridin clay (trade name), Quincy, Fla.	1.1	1.2	1.4	1.6	.9	1.1	1.2	1.4	5	4	1	20
Fuller's earth, Macon, Ga.	1.0	1.3	1.5	1.9	1.1	1.4	1.6	1.7	6	3	1	25
Filtrol bentonite, Chambers, Ariz.	.2	.3	.4	.4	1.8	2.5	2.9	3.4	5	4	1	25

Samples taken in sequence at 5- to 10-foot intervals from base of formation (T-21) to point 86 feet above base (T-31).

The samples tested from Kentucky were collected from outcrops and drill holes along Bee Creek, about 1 mile north of Murray, Calloway County.

Intervals were calculated on a basis of an apparent regional dip of 75 feet to the mile. The cut bank on the Foster farm is about 3,100 feet west of the bridge on State Highway 95 at Bee Creek.

Bleaching tests of Porters Creek clay near Murray, Ky.

	Raw				Acid-treated				Acid removal			
	G	Y	R	B	G	Y	R	B	Fe	Al	Ca	Off (percent)
K-1	0.6	0.7	0.8	0.9	0.6	0.7	0.8	0.9	7	3	Tr.	20
K-2	.6	.7	.8	.8	.6	.8	.9	1.1	7	3	Tr.	20
K-3	.5	.6	.7	.9	.7	.9	1.0	1.1	7	3	Tr.	20
K-4	.6	.7	.8	.9	1.0	1.2	1.4	1.5	6	4	Tr.	25
K-5	.6	.8	1.0	1.1	1.1	1.1	1.2	1.3	6	4	Tr.	25
K-6	.6	.7	.8	.9	1.0	1.2	1.4	1.5	7	3	Tr.	25
K-7	.7	.9	1.0	1.1	1.0	1.1	1.3	1.4	7	3	Tr.	25
K-8	.6	.9	.9	1.0	.9	1.1	1.2	1.4	6	4	Tr.	25
K-9	.6	.8	.9	1.0	.6	.7	.9	1.1	6	4	Tr.	30
K-10	.5	.7	.8	.9	.7	.9	1.0	1.1	6	4	Tr.	30
K-11	.6	.7	.8	1.0	.6	.8	.9	1.1	6	4	Tr.	25
K-12	.7	.9	1.0	1.2	.7	.9	1.1	1.2	6	4	Tr.	25
K-13	.5	.6	.6	.6	.7	.8	1.0	1.1	5	5	Tr.	30
K-14	.5	.6	.6	.7	.6	.9	1.0	1.1	6	4	Tr.	30
K-15	.6	.7	.8	.9	.7	.8	.9	1.1	6	4	Tr.	20

K-1. Cut bank of Bee Creek on Roy Foster farm, near top of formation.
K-2. 5 feet below K-1.
K-3. 5 feet below K-2.
K-4. Test hole 1, at foot of cut bank, about 10 feet below K-3.
K-5. 10 feet below K-4.
K-6. Test hole 10, 1,200 feet east of hole 1 (W. H. McKeel farm), about 10 feet below K-5.
K-7. Test hole 14, 600 feet east of hole 10 (W. H. McKeel farm), about 8 feet below K-6.
K-8. Test hole 9, 450 feet east of hole 14 (W. H. McKeel farm), about 5 feet below K-7.
K-9. Test hole 12, 500 feet east of hole 9, and about 350 feet west of State Highway 95, about 12 feet below K-8.
K-10. Test hole 2, 400 feet east of hole 12, just east of Highway 95, approximately same position as K-9.
K-11. Test hole 2, 400 feet east of hole 12, just east of Highway 95, 6 feet below K-10.
K-12. Test hole 7, 800 feet east of hole 2, S. W. Askew farm, 15-20 feet below K-11.
K-13. Test hole 3, Newt Parker's farm, about half a mile east of junction of Bee Creek with Clarks River, 60-70 feet below K-12, near base of formation.
K-14. Outcrop near hole 3, about 5 feet above K-13.
K-15. Outcrop 4 miles north of Benton on Highway 95, probably in upper half of formation.

Conclusions.—From the results of these tests it seems that much of the clay at the locality northeast of Pinson is as good a natural bleaching clay as the material being mined at Olmstead, Ill. It may even be better. Very large tonnages of the clay with comparatively little overburden are easily accessible at this locality. The location is within three-quarters of a mile of the Mobile & Ohio Railroad at Pinson, and a fairly good, unsurfaced road leads to Pinson.

As the formation appears rather uniform over large areas in Tennessee so there are perhaps other localities where the clay would prove equally good as a bleaching agent. If so, the supply would appear to be practically inexhaustible. However, before any large operations are attempted, further prospecting would be necessary. The question of possible markets would also have to be considered.

The series of samples of the Porters Creek clay north of the Tennessee line, near Murray, in Calloway County, Ky., is of a quality nearly equal to that of the material from Olmstead, Ill., but not as good as that of the Tennessee samples here tabulated. This is one of the few localities in Kentucky where the formation is exposed to any considerable extent; it is less accessible and less easily mined than the clay near Pinson, Tenn.

CERAMIC CLAYS OF WESTERN TENNESSEE

Western Tennessee and the adjacent part of western Kentucky produce most of the good ball clays of the United States, and in addition produce less valuable clays of the wad, sagger, and pottery types. The ceramic industry of the region will not be discussed here, because it has been covered in several reports, including an earlier one by the United States Geological Survey,[46] two States reports,[47] and a brief résumé which recently appeared in Ceramic Age.[48]

In this investigation it seemed advisable to confine the work to getting additional information on potential reserves of ball clays, as most of the mining operations are in these clays. The best ball clays are confined to the Holly Springs sand, of the Wilcox group (lower Eocene), and consist of a very plastic clay, remarkably smooth and free of grit, with a rather high fusion point, burning white to cream-colored, and with strong bonding properties. Such clays are extensively used in the ceramic industry. The ball clays occur as lenses of varying size in a formation that is dominantly sandstone and are exposed in few natural outcrops. The good clay deposits are commonly overlain by more sandy clays of the wad or sagger type, followed by sands. In many places a bed of lignite lies between the sands and the underlying clay deposits, and some of the best ball clays are dark with carbonaceous material. In the northern part of western Tennessee, as in western Kentucky, a blanket deposit of gravel generally covers the sands and clays of the Holly Springs formation. It is therefore difficult to discover new deposits of these ball clays, though the number already known makes it very probable that many additional beds will be found. The accidental discovery of such deposits in the course of drilling water wells in the region will doubtless continue, and more intensive campaigns of prospecting by boring for the clays will probably be undertaken by the operating companies as the large reserves now available approach exhaustion.

Many natural and artificial cuts into the Holly Springs sand in western Tennessee have exposed clay beds of varying quality. In general these clays are sandy and not of the ball-clay grade. However, as the best ball clays are commonly overlain by poorer, sandy clays, it seemed probable that boring into these clay outcrops might penetrate some ball clays of good quality. The greater erosion of the Holly Springs and the less prevalent gravel overburden in Hardeman County made this region favorable for prospecting by boring. Some prospecting was also done in Carroll County, as clay outcrops are not uncommon, and the county adjoins Henry County, where extensive deposits of ball clays are being mined.

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46 Ries, Heinrich, High-grade clays of the eastern United States: U. S. Geol. Survey Bull. 708, 1922.

47 Nelson, W. A., Clay deposits of west Tennessee: Tennessee Geol. Survey Bull. 5, 1911. Schroeder, R. A., Ball clays of West Tennessee: Resources of Tennessee, vol. 9, no. 2, April 1919.

48 Whitlatch, G. I., The ceramic industries of west and middle Tennessee: Ceramic Age, January-February 1934.

BALL-CLAY INVESTIGATIONS IN HARDEMAN COUNTY

Clay beds in the Holly Springs sand are perhaps no more common in Hardeman County than elsewhere, but the more general cutting into the bedrock by stream erosion has exposed more clays in outcrops than is general in western Tennessee. No considerable ball-clay deposits have been found in this county, but the conditions for their occurrence in the Holly Springs formation appear much the same as those in Henry County. Several of these clay outcrops were therefore tested by boring, and some of the more promising occurrences are discussed below in detail. Figure 18 indicates the general location of these

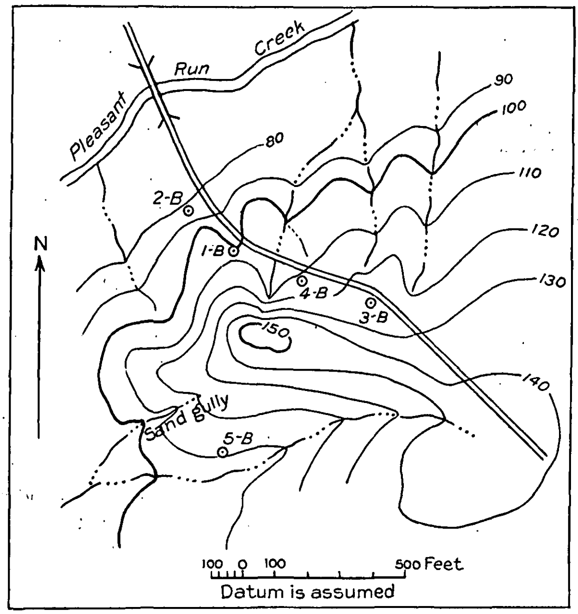


FIGURE 20.—Sketch map showing location of test holes northwest of Bolivar, Hardeman County, Tenn. (By J. B. Preston.)

occurrences in the county, and detailed sketch maps of the particular areas prospected are presented. As there are no topographic maps of the areas, altitudes are shown relative to an assumed altitude of 100 feet at some arbitrary point.

A large exposure of clay occurs about 2 miles northwest of Bolivar, indicated as 2 in figure 18. This gray sandy clay is exposed in the road cut along Highway 72, and details of the locality are shown in figure 20. The following are logs of the test holes shown on this map:

Hole 1–B (assumed altitude 100 feet)

	Ft.	in.
Clay, sandy, gray (exposed)	1	6
Clay, dark brownish gray, slightly sandy (sample 53)	25	
	26	6

Hole 2–B (relative altitude 81 feet)

	Ft.	in.
Clay, sandy, gray	10	
Sand, gray and clayey		6
Clay, sandy, gray	15	
	25	6

Hole 3–B (relative altitude 120 feet)

Clay, gray, plastic, with very little grit; exposed	2	
Clay, light gray, slightly sandy	1	6
Sand, yellow, soft	23	6
	27	

Hole 4–B (relative altitude 110 feet)

Clay, light gray, micaceous, slightly sandy	5	
Clay, brown, micaceous, slightly sandy	8	6
Sand, yellow, and sandy clay		6
Clay, brown, micaceous, slightly sandy		6
Clay, brownish gray, slightly sandy	10	6
	25	

Hole 5–B (relative altitude 111 feet)

Sand, yellowish to gray, soft	25	

Sample 53, a composite sample from hole 1–B, 0 to 25 feet, was tested (see p. 16), and the following results indicate that the clay is suitable for use in white-ware bodies, but that it is not of good ball-clay grade:

Kind of clay, ball clay; color, gray; fracture, hackly; screen test, percent on 115 mesh, 0.1, on 150 mesh 0.2, on 200 mesh 0.3; working properties, good; clay has a smooth texture; drying conduct, good; water of plasticity, 36.2 percent; shrinkage water, 16.4 percent; pore water, 19.8 percent; volume drying shrinkage based on dry volume, 28.1 percent; linear drying shrinkage based on dry length, 9.4 percent; dry strength, modulus of rupture with 50 percent potter's flint, 217 pounds to the square inch; firing behavior, pyrometric cone equivalent, 31.

Cone	Porosity (percent)	Firing shrinkage (percent)		Color
		Volume	Linear	
06	38.1	4.5	1.5	White.
04	35.0	7.9	2.7	Light cream.
02	29.1	13.6	4.8	Do.
2	25.7	17.9	6.4	Do.
4	24.6	18.4	6.6	Do.
6	24.2	18.4	6.6	Do.
7	21.2	20.3	7.3	Do.
9	10.4	28.2	10.6	Very light gray.
11	3.3	30.2	11.3	Gray, bluestoned.
13	0.0	31.1	11.7	Do.
15	5.9	18.0	6.4	Light brown.

General remarks: The clay is plastic and has good drying characteristics. The drying shrinkage is not excessive. The fusion point is relatively high, and the firing characteristics are reasonably good. The modulus of rupture of the dried pieces is fair but not exceptional. However, when the clay is mixed with flint it becomes rather rubbery. It can be used as a component of white-ware bodies.

The test holes show a considerable tonnage of clay here, owing to the thickness of the deposit in holes 1–B and 4–B, but the lateral extent is not great, as indicated by holes 2–B and 3–B. The deposit would therefore appear of value only in supplying clay for a local pottery plant.

Another deposit of clay on Highway 72 about 3¾ miles northwest of Bolivar, crops out in a deep gully on the south side of the road on the property of H. E. Carter. The exposure shows 5 to 10 feet of gray sandy clay, and a test hole gave the following section:

Hole 1–C

	Ft.	in.
Clay, gray, sandy	1	0
Sand		6
Clay, sandy, gray, micaceous	5	6
Clay, sandy, dark gray (sample 51)	6	6
Clay, sandy, light gray	6	0
Clay, sandy, gray with red mottling		6
Clay, sandy, light gray, with streaks of sand	1	6
	21	6

Ceramic tests on sample 51 gave a fusion point of cone 30, with a tendency to overfire at cone 15. All of this clay was rather sandy, and as the burning tests were not particularly good, it was not tested further, and no map of this locality is presented.

In a gully on the northwest side of the Middleburg road, 4 miles southwest of Bolivar, 10 feet of gray sandy clay is exposed. A test hole in this gully penetrated an additional 3 feet of this sandy clay and then went into sand. Details of this occurrence are not presented, as the material did not appear worth ceramic testing.

On the Edwin Patrick farm, 4 miles northeast of Bolivar (locality 3 in fig. 21), several exposures of clay and lignites in the stream cuts were tested by borings. Details of this locality are shown in figure 21, and the logs of the test holes follow:

Hole 1–P (assumed altitude, 110 feet)

	Ft.	in.
Lignite, overlain by sandy clay and sand; exposed	5	0
Clay, gray, slightly sandy and lignitic (sample 54)	10	0
Sand, clayey	1	0
Clay, dark gray, slightly sandy	3	0
Lignite	2	0
Clay, dark brown, slightly sandy and lignitic	3	0
Clay, dark grayish brown, slightly sandy	2	0
Lignite, brown	2	0
Clay, black, lignitic	2	0
	30	0

66911—40——14

Hole 2–P (relative altitude, 117 feet)

	Ft.	in.
Sand, soft	7	6
Clay, sandy, gray	8	6
Clay, sandy, gray and yellow	1	0
Clay, sandy, dark gray	1	6
Sand, gray, clayey	6	6
	25	0

Hole 3–P (relative altitude, 117 feet)

	Ft.	in.
Soil and sand	6	0
Clay, sandy, and fine sand	11	0
Clay, sandy, grayish brown	1	0
Sand, gray, clayey	2	0
Clay, dark gray, slightly sandy	1	6
	21	6

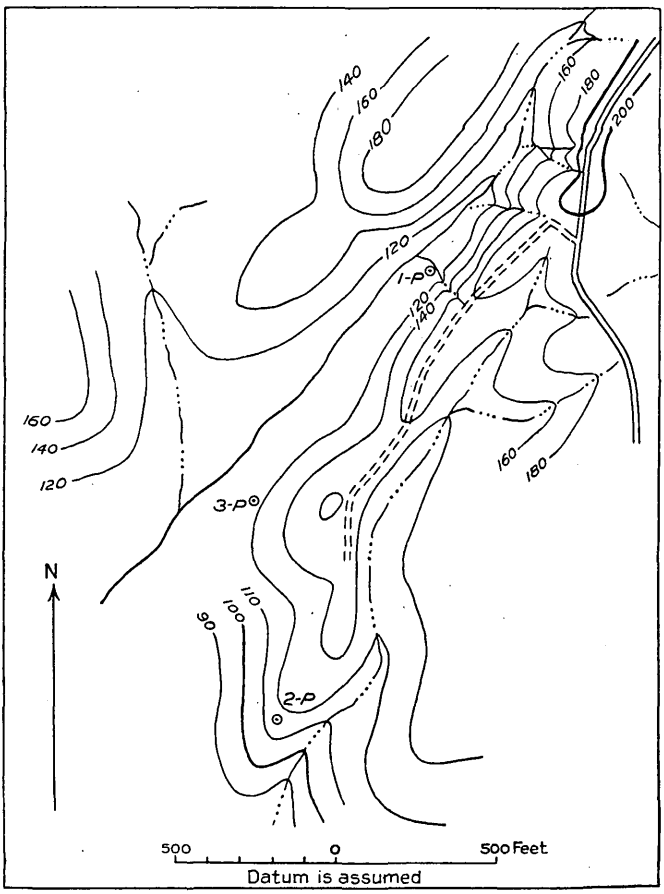


FIGURE 21.—Sketch map of Patrick farm, northeast of Bolivar, Hardeman County, Tenn., showing location of test holes. (By J. B. Preston.)

These few test holes indicate the presence of a thick and extensive deposit of clay on this property, but much of it is rather sandy, particularly southward in holes 2–P and 3–P, though the entire thickness of the deposit was not penetrated in these test holes. Sample 54, from hole 1–P, was tested with the following results:

Kind of clay, ball; color, gray and black; fracture, hackly; screen tests, percentage on 115 mesh 0.3; on 150 mesh 0.2, on 200 mesh 0.7; working properties, very plastic; drying conduct, good; clay washed through 115 mesh before testing; water of plasticity, 37.3 percent; shrinkage water, 17.8 percent; pore water, 22.6 percent; volume drying shrinkage, 30.4 percent; linear drying shrinkage, 11.0 percent; dry strength, modulus of rupture with 50 percent potter's flint, 247 pounds to the square inch; firing behavior, pyrometric cone equivalent, 31.

Firing tests

Cone	Porosity (percent)	Firing shrinkage (percent)		Color
		Volume	Linear	
06	37.7	4.4	1.4	White.
04	36.0	7.4	2.5	Do.
02	32.9	10.2	3.5	Do.
2	30.0	15.3	5.4	Do.
4	29.0	15.6	5.5	Do.
6	27.0	17.3	6.1	Light cream.
7	24.5	20.1	7.2	Do.
9	14.3	25.3	8.3	Do.
11	10.4	26.4	9.7	Light-gray bluestone.
13	4.0	29.8	11.1	Do.
15	1.1	31.5	11.9	Light brown.

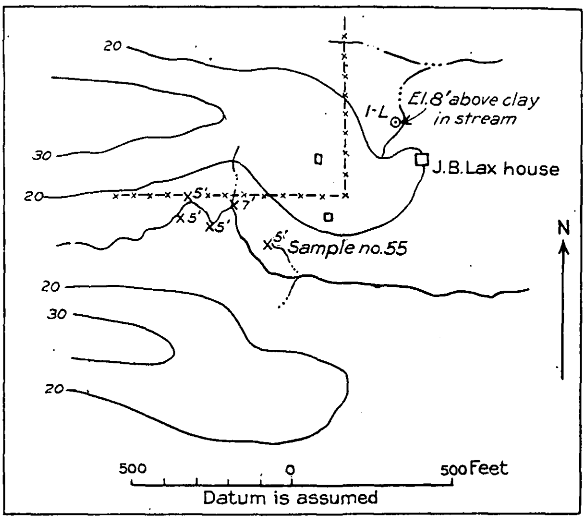


FIGURE 22.—Sketch map of Lax farm, near Saulsbury, Hardeman County, Tenn., showing location of test holes. (By J. B. Preston.)

General remarks: The clay has a fusion point of cone 31, which is moderately high. It is fairly strong, as shown by its modulus of rupture. It can be considered a rather open-burning ball clay and should be very suitable for saggers.

These test holes and the results of the ceramic tests on a single sample suggest a possibility of finding a large deposit of ball clay with more intensive prospecting on this property. The location is about 2 miles by road to the nearest point on the Illinois Central Railroad at Shandy and is in a rather rugged district with a maximum overburden of about 70 feet of sand.

A deposit of clay on the S. A. Wheeler farm, 1¼ miles south of Bolivar, was tested by three bore holes, which indicate that the bed is 10 to 20 feet thick and extends over several acres. However, the ceramic tests on two samples showed a poor grade of clay that was not very plastic and with a fusion point of only cone 27 for the more refractory one. Therefore, no details of this occurrence are presented.

A clayey lignite exposed on the 600-acre farm of David Wood and Will Wood, about 7½ miles west of Bolivar, was drilled but was found to be underlain by very sandy clays and clayey sands and was therefore not tested further. The outcrop of clay on the J. R. Young farm, 1 mile northwest of Shandy, also appeared to be of no value, as it was very sandy throughout the test hole.

A clay bed crops out at several places along stream cuts on the J. B. Lax place, at the southwest edge of the town of Saulsbury (location 4 in fig. 18), as shown on figure 22. This bed ranges from 5 to 7 feet in thickness in the exposures along the stream. Test hole 1–L did not penetrate any clay to the total depth of 18 feet, though it was at an altitude that should include the clay horizon if present. However, this hole is at some distance from the outcrops, and these outcrops indicate that the clay bed extends over an area several hundred feet square, at least.

The following ceramic tests on sample 55, from an outcrop in a creek about 500 feet southwest of the J. B. Lax place, indicate that this clay may be of value for white ware, and that the deposit may be worth some additional prospecting, which would not be difficult, for the maximum overburden would be only about 30 feet of sand. The deposit is about 1,000 feet from the Southern Railway station at Saulsbury.

Kind of clay, ball clay; color, gray with pinkish tinge; fracture, hackly; screen test, percent on 115 mesh, 0.1; on 150 mesh, trace; on 200 mesh, trace; working properties, very plastic and rather fat; drying conduct, good; modulus of rupture with 50 percent potter's flint, 126 pounds to the square inch; water of plasticity, 39.7 percent; shrinkage water, 18.5 percent; pore water, 21.2 percent; volume drying shrinkage, 29.9 percent; linear drying shrinkage, 11.2 percent; firing behavior, pyrometric cone equivalent, 32.

General remarks: The clay has a rather high fusion point. The dry strength is not exceptionally good, as shown by its modulus of rupture. The water of plasticity and the linear drying shrinkage are fairly high. The clay fires to a good dense body at cone 13 and slightly overfires at cone 15. However, its fired color, even at cone 15, is remarkably good, as it is light gray. This clay appears to be of considerable value for use in the white-ware industry and should be further investigated for this purpose.

Firing tests

Cone	Porosity (percent)	Firing shrinkage (percent)		Color
		Volume	Linear	
06	39.6	6.1	2.1	White.
04	36.4	10.1	3.5	Do.
02	31.2	16.5	5.8	Do.
2	26.2	20.8	7.5	Light cream.
4	26.2	21.3	7.7	Do.
6	24.9	23.0	8.4	Do.
7	22.0	25.1	9.2	Do.
9	14.5	30.6	11.5	Do.
11	7.6	34.2	13.0	Light gray, slightly bluestoned.
13	00.0	37.0	14.3	Do.
15	00.0	35.6	13.6	Do.

BALL-CLAY INVESTIGATIONS IN CARROLL COUNTY

On the farms of A. H. Gowan and F. W. Organ, about 1½ miles east of Wood Hill, there is an extensive and very thick bed of clay. Test holes were bored in several places over a large area. Four test holes of 25 to 30 feet in clay were drilled on the Gowan farm and four test holes of 20 to 25 feet on the Organ farm. Most of these holes ended in clay without having penetrated the total thickness. However, two samples of this clay from the Gowan farm were tested with rather disappointing results, as indicated below, though the deposit is so large and thick that more thorough testing might find some better clay.

Sample 58, hole 2–A, depth 4–9½ feet; kind of clay, ball clay; color, gray; fracture, hackly; screen tests, percent on 115 mesh, 0.6; on 150 mesh 0.2; on 200 mesh 0.3; working properties, good; drying conduct, satisfactory; water of plasticity, 32.6 percent; shrinkage water, 14.4 percent; pore water, 18.1 percent; volume drying shrinkage, based on dry volume, 25.8 percent; linear drying shrinkage, based on dry length, 9.3 percent; dry strength, modulus of rupture with 50 percent potter's flint, 132 pounds to the square inch; firing behavior, pyrometric cone equivalent, 29.

Firing tests

Cone	Porosity (percent)	Firing shrinkage (percent)		Color
		Volume	Linear	
06	35.5	2.7	0.9	Light cream.
04	33.9	7.0	2.4	Do.
02	32.0	8.5	2.9	Do.
2	26.4	15.4	5.4	Do.
4	22.5	19.0	6.8	Do.
6	19.4	21.5	7.8	Do.
7	19.4	21.8	7.9	Dark cream.
9	1.4	31.3	11.8	Gray, blue stoned.
11	.4	32.2	12.2	Do.
13	10.6	27.9	10.3	Do.
15	16.0	15.1	5.3	Brownish gray.

General remarks: This clay is of rather poor quality, as the fusion point is comparatively low. The modulus of rupture is low, and the porosity drops suddenly between cones 7 and 9, with a tendency to develop a marked bleb structure. It is a poor grade of ball clay.

Sample 60, hole 1–A, depth 22–24½ feet; color, black; kind of clay, bond clay; fracture, hackly; screen tests, small residue on each screen; working properties, excellent; drying conduct, good; water of plasticity, 39.7 percent; shrinkage water, 22.0 percent; pore water, 17.1 percent; volume drying shrinkage based on dry volume, 39.1 percent; linear drying shrinkage based on dry length, 15.3 percent; dry strength, good, very dense structure; firing behavior, pyrometric cone equivalent, 29.

Firing tests

Cone	Porosity (percent)	Firing shrinkage (percent)		Color
		Volume	Linear	
02	30.1	13.5	4.7	White.
2	28.0	16.0	5.6	Light cream.
4	24.8	18.7	6.7	Do.
6	22.1	20.4	7.3	Do.
7	17.5	23.3	8.5	Do.
9	11.2	24.6	9.0	Light gray.
11	7.3	25.1	9.2	Light gray, blue stoned.
13	2.0	29.3	10.9	Gray, blue stoned.
15	12.0	20.7	7.5	Brown.

General remarks:

The sample selected was small, and came from a relatively thin stratum in the deposit. It is probably satisfactory for use as a bond clay, but fires to too dark a color for a ball clay.

A clay deposit on the Frank Adamson farm, about 5 miles west of Huntingdon, is now controlled by Fred Tate, as manager for the West Tennessee Clay Co. (See fig. 18, locality 5.) This clay appears to be of good quality and is a large deposit with no excessive overburden. The details of this occurrence are shown on figure 23, and the logs of the three test holes follow:

Hole 1–A (assumed altitude 100 feet)

	Ft.	*in.*
Clay, brown, laminated, slightly sandy	7	0
Clay, gray, laminated, slightly sandy (sample No. 61)	8	0
Sand, gray, with clay streaks	4	0
Sand, yellow, clayey	6	0
	25	0

Hole 2–A (altitude 109 feet)

Sand, buff, slightly clayey	6	6
Sandy clay, yellow	1	0
Sand, gray, clayey	3	0
Sand, gray	1	0
Sandy clay, gray		6
Sand, yellow, fine	4	6
Clay, gray, plastic		3
Sand, yellow and gray	8	0
	24	9

Hole 3–A (altitude 128 feet)

	Ft.	in.
Clay, brown, laminated, slightly sandy	6	6
Sand, gray		3
Clay, brown, laminated, slightly sandy	6	
Sand, gray		3
Clay, brown, laminated, slightly sandy	2	6
Clay, dark greenish brown, slightly sandy	9	6
	25	

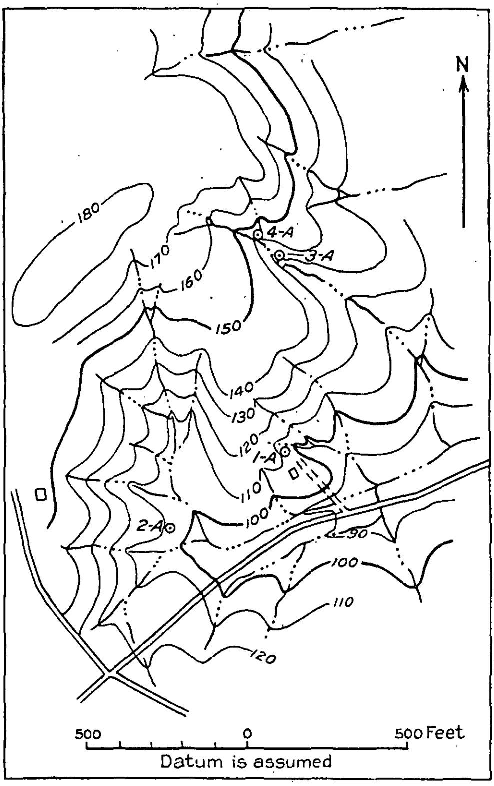


FIGURE 23.—Sketch map of Adamson farm, 5 miles west of Huntingdon, Carroll County, Tenn., showing location of test holes. By J. B. Preston.

The following ceramic tests on sample 61 of the clay from hole 1–A indicate that the clay should be suitable as a refractory bond clay:

Kind of clay, refractory bond clay; color, chocolate brown; fracture, hackly; screen tests, trace of residue on 115, 150, and 200 mesh sieves; working properties, very plastic; drying properties, satisfactory; water of plasticity, 47.4 percent; shrinkage water, 28.5 percent; pore water, 18.9 percent; volume drying shrinkage based on dry volume 46.2 percent; linear drying shrinkage based on dry length 18.7 percent; dry strength good; modulus of rupture with 50 percent potter's flint, 520 pounds to the square inch; firing behavior, pyrometric cone equivalent, 31.

Firing tests

Cone	Porosity (percent)	Firing shrinkage (percent)		Color
		Volume	Linear	
06	37.0	6.2	2.1	White.
04	35.2	9.5	3.3	Do.
02	29.0	16.5	5.8	Do.
2	26.8	19.2	6.9	Light cream.
4	25.7	20.0	7.2	Do.
6	24.1	22.0	7.9	Do.
7	21.6	24.7	9.0	Do.
9	14.2	27.2	10.0	Very light gray, bluestoned.
11	9.8	30.5	11.5	Light gray, bluestoned.
13	2.0	33.0	12.5	Gray, bluestoned.
15	.7	33.8	12.9	Brown.

General remarks: This clay is almost unique because it has a very high volume drying shrinkage but has a good strong dense body without cracks. The clay has an exceptionally high modulus of rupture, is fairly refractory, and should prove a valuable bond clay for crucibles, etc. Also, it is a remarkably open-firing type of clay, as minimum porosity is attained at cone 15 without overfiring.

CONCLUSIONS

The results of the boring tests in Hardeman and Carroll Counties indicate that large deposits of first-class ball clays are not to be found underlying most of the sandy clay "blossoms" in the Holly Springs sand in western Tennessee. However, the clay outcrops tested were necessarily only a small part of the total outcrop, and the deposits tested by boring were not thoroughly explored because in general the results obtained did not appear of sufficient promise to justify additional work. Some of the clay deposits reported on here, though not first-grade ball clays, are of value for particular purposes and will perhaps be worth development. The results do not disprove the presence of large reserves of good ball clays, for the numerous ball-clay deposits already found underneath the cover of gravel and sand make it seem very probable that large deposits yet remain undiscovered.

A brief reconnaissance examination of possible fire clays occurring as underclays of coal seams in the Pennsylvanian coal measures of eastern Tennessee was made by J. Basil Preston, to assist George I. Whitlatch in this work, and the results will be reported upon by Mr. Whitlatch for the Tennessee Division of Geology.

CERAMIC CLAYS IN KENTUCKY

Prospecting for ceramic clays in Kentucky was not attempted because outcrops of the Holly Springs sand are few, and the heavy gravel overburden makes boring very difficult and with few chances of success, because no surface indications of a clay lens can be seen in the formation, which is dominantly sandstone.

CHAPTER 6.—SOME CERAMIC CLAYS IN ALABAMA

By M. N. BRAMLETTE and T. N. MCVAY

INTRODUCTION

Investigations by the Geological Survey in Alabama and adjacent States in 1934 included work on some ceramic clays, with results presented in this report.

Many ceramic clays, including a wide variety of types, were known to occur in the State. Most of these deposits were examined, and those of greatest promise were prospected, sampled, and tested. The results indicate that some of the best clays are large deposits of kaolin and plastic refractory clay in Marion County. Clays of probable commercial value also occur in DeKalb, Talladega, Bibb, and Baldwin Counties. Figure 24 is a key map of Alabama outlining the areas where work was done, and plate 6 is a map of southern Alabama showing the localities prospected for clay.

Scope of investigations.—The work here described was a detailed reconnaissance based in general on information made available through the School of Chemistry, Metallurgy, and Ceramics of the University of Alabama, which had made a preliminary survey of the clay resources of the State with funds supplied by the Alabama Industrial Board. Professor McVay, the head of this school, was familiar with this previous work, having made the preliminary ceramic tests on 1,275 samples sent by residents from many parts of the State. Most of these samples represented material that had little or no apparent value, but some appeared to be worth investigation. The Geological Survey party was given the results of this earlier work and made an effort to visit every locality from which one of these more promising samples had come. The amount of work done at any place depended on the nature and extent of the deposit represented by the sample and its general promise as indicated by the apparent quality and field relations of the material. Though in some places enough work was done to give qualitative ideas regarding the size of a deposit, it was not practicable under the conditions imposed by time and methods of work to make quantitative estimates of tonnage.

Field and laboratory examination.—The field work, which was under the supervision of Mr. Bramlette, was carried on largely by H. S. Rankin, a temporary employee, and two assistants. All possible

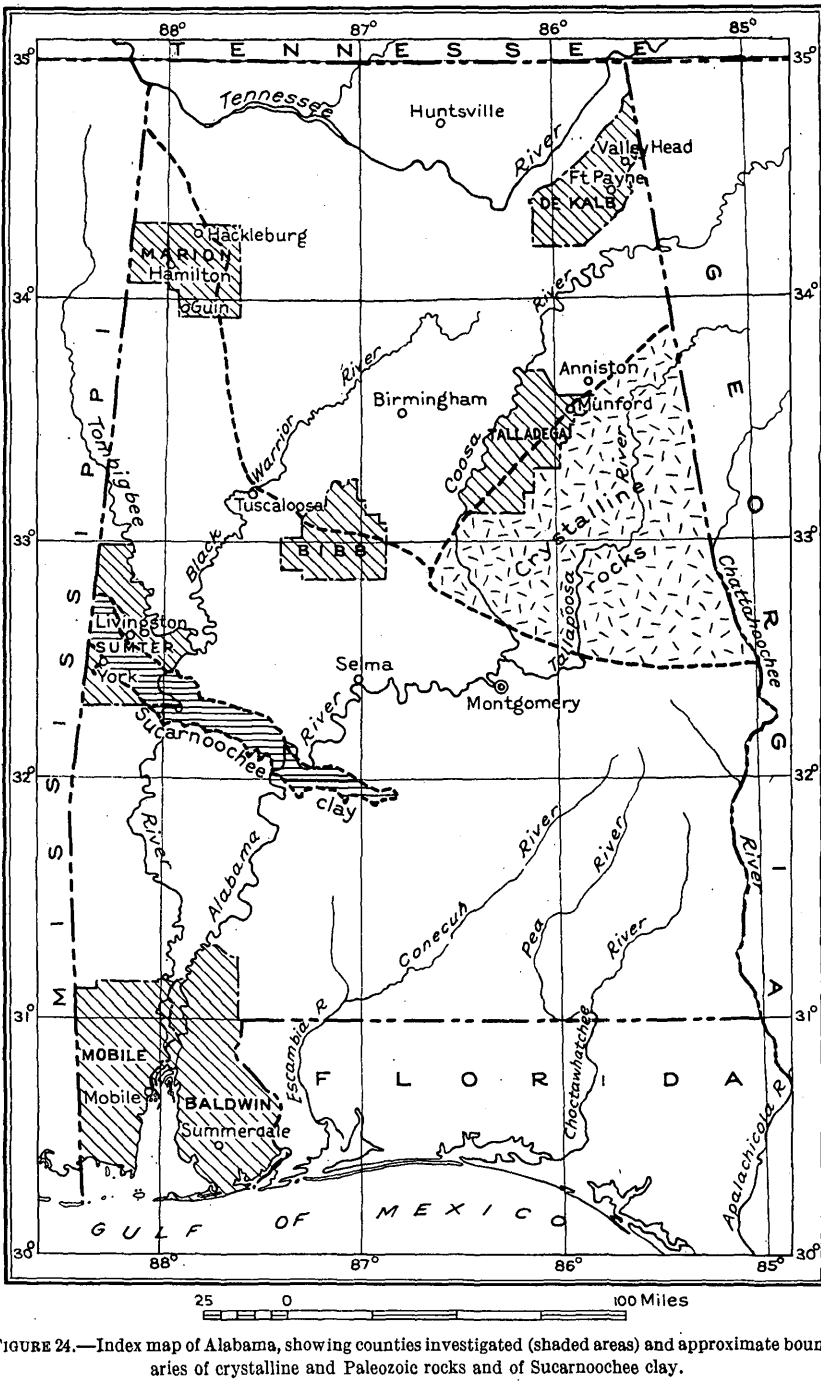


FIGURE 24.—Index map of Alabama, showing counties investigated (shaded areas) and approximate boundaries of crystalline and Paleozoic rocks and of Sucarnoochee clay.

outcrop data were obtained in both natural and artificial exposures. In addition a considerable number of borings were made with a 3-inch Iwan auger, fitted with extra 4-foot joints of ¾-inch pipe sufficient for boring to depths of 25 to 30 feet. Measurements of thickness were obtained and samples were collected for testing.

The samples were sent to the laboratories of the University of Alabama, where they were tested under the supervision of Professor McVay, whose procedure is described on pages 16–19. His results are embodied in this report.

CERAMIC CLAYS IN ALABAMA

Clays occur in Alabama in wide variety, and a comprehensive examination of all these deposits would require more time than was available for this work. The better clays are largely confined to the few counties in which the present work was done. Among these clays are included good kaolins, sandy kaolins, residual fire clays, plastic fire clays, bauxitic clays, and many deposits of pottery clays and brick clays. As the pottery and brick clays are abundant, and of less commercial value, these types were not investigated. Good bond or ball clays, such as occur in western Tennessee and Kentucky, are apparently scarce or lacking.

The classification of clays is difficult, and no entirely satisfactory scheme has ever been presented. Hence no attempt will here be made to discuss a classification. The clays are merely designated according to common usage in considering the individual occurrences, and are discussed by counties, any one of which may contain several different types of clay. Some of these clay deposits were investigated in a preliminary field examination, and only the more promising beds were explored by drilling, sampling, and testing.

CLAYS IN MARION COUNTY

In Marion County clay deposits are extensively developed at the contact of the Pennsylvanian with the overlying Upper Cretaceous Tuscaloosa formation. Some clays also lie within the lower part of the Tuscaloosa, but these are thin lenses of small extent. The more extensive clay deposits at the Pennsylvanian-Tuscaloosa contact vary in character and thickness and include good kaolins, sandy kaolins, and more plastic clays of varying quality. These clays have previously been placed in the lower part of the Tuscaloosa formation and thus considered of Upper Cretaceous age. Some evidence is here presented to indicate why they are now placed with the underlying Pennsylvanian formations and should therefore be classed as residual clays, formed on this old surface, rather than as transported or sedimentary clays of the Tuscaloosa formation.

KAOLIN DEPOSITS OF THE CHALK BLUFF AREA

In northern Marion County, about 5 miles south of Hackleburg, the clays developed at the Pennsylvanian-Tuscaloosa contact include the best kaolin deposits known in the region. Figure 25 shows the location of previous test pits and of the borings made during the present work in the Chalk Bluff area. The name "Chalk Bluff" is in local use for one of the more conspicuous white clay banks. The name is thus a misnomer, because no actual chalk is present. The following logs of test holes, shown on the map, give some data on the extent and character of these clay deposits:

Hole 1 (altitude 90 feet above Camp Creek)

[Bored in old clay pit, and top of clay bed therefore not included]

	Ft.	*in.*
Clay, white	6	
Clay, white, with some sand; (at 8 feet the auger was in yellow sand)	2	
	8	

Hole 2 (altitude 91 feet above Camp Creek)

[Bored in old clay pit, and top not included]

	Ft.	in.
Clay, smooth, white	7	0
Sand, yellow	2	0
	9	0

Hole 3 (altitude 92 feet)

	Ft.	in.
Outcrop above collar of drill hole:		
Ironstone caprock		3
Clay, sticky, gray (sample 161–3)	2	6
Lignite, probable base of Cretaceous		3
Clay, soft, mottled gray and yellow	1	0
Kaolin, hard, red and yellow		3
Kaolin, smooth, white	1	0
Section in drill hole:		
Kaolin, smooth, white (sample 161–1)	9	0
Clay, white, with some yellow sand	5	0
	19	3

Hole 4 (altitude 88 feet)

[Bored in bottom of old pit]

	Ft.	in.
Sandy clay	6	0
Yellow sand.		

Hole 5 (altitude 105 feet)

	Ft.	in.
Sand, coarse, white	6	0
Sand, white	3	0
	9	0

Hard ironstone caprock, clay not reached.

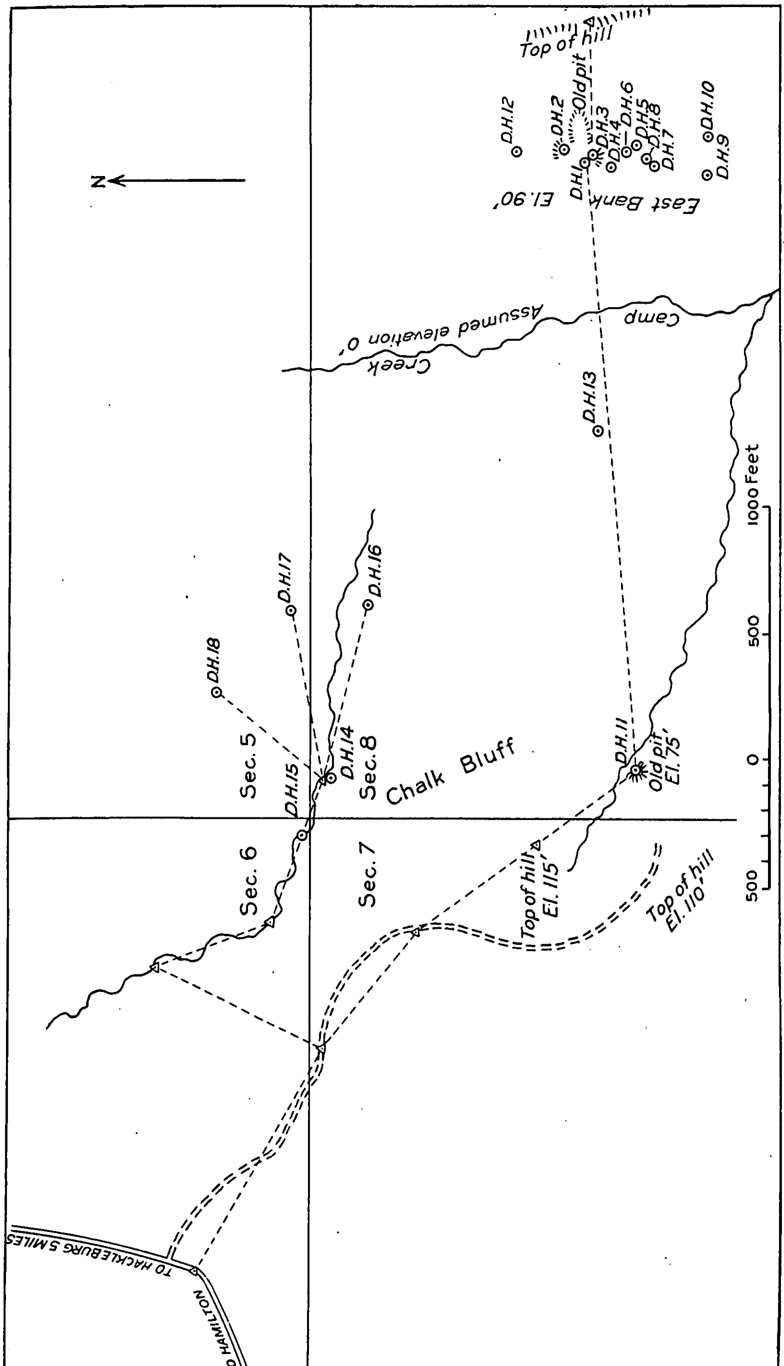


FIGURE 25.—Sketch map of Chalk Bluff area, Marion County, Ala., showing location of test holes. By H. S. Rankin.

Hole 6 (altitude 90 feet)

	Ft.	in.
Surface soil and sand	2	0
Clay, hard, smooth, white	1	0
Clay, white, with some sand	5	0
Sand, yellow	2	0
	10	0

Hole 7 (altitude 88 feet)

Clay, white, hard, gritty (exposed in cut)	7	0
Clay, white, with some sand	5	0
Sand, yellow	2	0
	14	0

Hole 8 (altitude 102 feet)

Sand	5	0
Hard ironstone caprock; clay not reached.		

Hole 9 (altitude 81 feet)

Sand, yellow	15	0

Hole 10 (altitude 104 feet)

Sand	13	0
Hard ironstone caprock; clay not reached.		

Hole 11 (altitude 75 feet west side of valley above Camp Creek)

Exposed in old pit above collar of drill hole:		
Ironstone caprock		4
Clay, soft, pink		4
Clay, hard, gritty, cream to white (sample 161–2)	4	0
Section in drill hole:		
Clay, hard, gritty, cream-colored	4	0
Clay, hard, gritty, mottled red and white	3	0
Sand, hard, with some clay	8	0
	19	8

Hole 12 (in old test pit)

Exposed above collar of drill hole:		
Surface sand and wash	6	0
Ironstone caprock, hard		6
Clay seams and sand	2	6
Section in drill hole:		
Clay seams and sand	7	0
Clay, hard, mottled yellow and white	6	0
Sand		6
	22	6

Hole 13

Surface wash and sand	3	0
Sand and clay	6	0
	9	0

Hole 14 (near old clay pit)

	Ft.	in.
Clay, gritty, white	2	6
Clay, hard, smooth, cream-colored	4	0
Clay, hard, smooth, white	5	0
Sand, white, and clay	5	6
	17	0

Hole 15

Surface soil and sand	3	0
Clay, hard, smooth, white	5	0
Sand, yellow, and clay	4	0
Sand, hard, yellow		6
Clay, hard, mottled gray	5	0
Clay, red, sand at bottom	1	6
	19	0

Hole 16

Surface soil and sand	2	0
Sandy clay, mottled red and yellow	7	0
Sandy clay, red	2	0
Clay, red	2	0
	13	0

Hole 17

Clay, mottled gray and yellow	13	6

Hole 18

Surface soil and sand	2	0
Clay, hard, white, gritty	4	0
Sand and yellow clay	1	0
Sand	2	0
	9	0

As indicated in the log of hole 3, a sample (161–1) was taken of this kaolin, and the ceramic tests follow. The plastic gray clay that immediately overlies the kaolin at this test hole was also sampled (161–3), and the results of the ceramic tests are presented on page 214. On the west side of Camp Creek at hole 11, this kaolin is somewhat sandy, and this type was sampled (161–2); the ceramic tests are given on page 214.

Sample 161–1, Thomas property, Chalk Bluff area, from upper part of kaolin at hole 3: Thickness, best clay, without sand, 10 feet; kind of clay, kaolin; color, white to cream; fracture, rather hackly; screen tests, percent on 115 mesh 0.1, on 150 mesh 0.1, on 200 mesh 0.1; working properties, clay slakes readily, thus differing from the kaolins Nos. 2 and 4, which are more indurated; the kaolin is plastic and can be readily molded; drying conduct, good; water of plasticity, 33.6 percent; shrinkage water, 10.2 percent; pore water, 23.4 percent; volume drying shrinkage based on dry volume, 16.3 percent; linear drying shrinkage based on dry length, 6.1 percent; dry strength, weak, with porous structure; firing behavior, pyrometric cone equivalent, above 33.

Firing tests

Cone	Porosity (percent)	Firing shrinkage (percent)		Color	Cone	Porosity (percent)	Firing shrinkage (percent)		Color
		Volume	Linear				Volume	Linear	
06	41.6	15.5	5.5	White.	7	31.3	25.1	9.2	White.
04	41.2	15.2	5.4	Do.	9	27.7	33.4	12.7	Do.
02	41.7	16.1	5.7	Do.	11	24.6	36.1	13.9	Do.
2	36.7	23.0	8.3	Do.	13	23.9	36.6	14.1	Do.
4	39.4	19.2	6.9	Do.	15	20.6	38.7	15.1	Do.
6	36.0	23.8	8.6	Do.					

Conclusions: The clay has a tendency to crack in firing, and this has probably caused the inconsistent results shown in the data on the fired test pieces. The clay is very refractory and is fine-grained. It probably would have its greatest use as an ingredient of white-ware bodies.

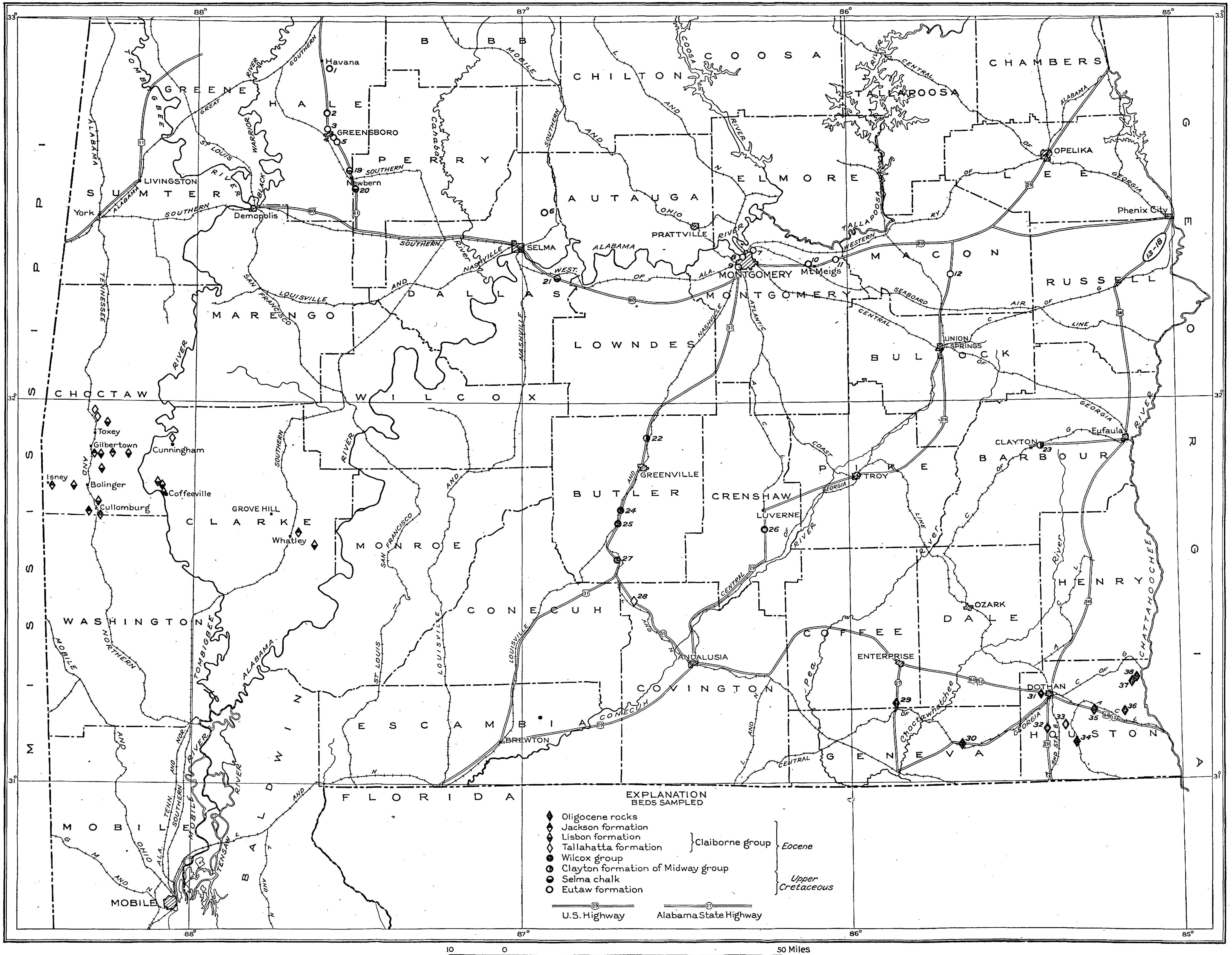
Sample 161–2, Thomas property, Chalk Bluff area, hole 11: Thickness, 8–10 feet; kind of clay, sandy kaolin; color, white with cream tint; fracture, conchoidal; screen tests, percent on 115 mesh 2.0, on 150 mesh 1.0, on 200 mesh 0.8; working properties, the clay is fairly plastic when finely ground; it is a rather poor slaking clay in cold water but slakes well in hot water; drying conduct, good; water of plasticity, 32.1 percent; shrinkage water, 9.1 percent; pore water, 23.0 percent; volume drying shrinkage based on dry volume, 14.7 percent; linear drying shrinkage based on dry length, 5.1 percent; dry strength, poor, but stronger than No. 4; firing behavior, pyrometric cone equivalent, above 33.

Firing tests

Cone	Porosity (percent)	Firing shrinkage (percent)		Color
		Volume	Linear	
06	43.6	10.7	3.6	All white with slight cream color.
04	42.5	12.8	4.5	Do.
02	43.8	13.7	4.8	Do.
2	42.4	15.5	5.5	Do.
4	40.9	17.8	6.2	Do.
6	39.3	18.7	6.6	Do.
7	36.3	23.0	8.4	Do.
9	29.8	30.2	11.3	Do.
11	28.9	30.8	11.5	Do.
13	27.8	31.0	11.7	Do.
15	22.8	33.3	12.7	Do.

Conclusions: The clay has an exceptionally high fusion point, as there is no sign of fusion at cone 33. The bonding properties are low, but this can be improved by fine grinding or slaking in hot water. The clay is more dense when fired than sample 161–4. As the clay will slake and does not contain any large amount of residue, it can possibly be used for white ware, as well as refractories. The characteristics of the clay are such that part of it would have to be calcined before use in refractories if the intention was to make a brick the major portion of which consisted of this material.

Sample 161–3, Thomas property, Chalk Bluff area, hole 3, above 161–1: Thickness, 2 to 3 feet; kind of clay, plastic fire or bond clay; color, brown when wet, gray when dry; fracture, hackly; screen tests, percent on 115 mesh 0.1, on 150 mesh trace, on 200 mesh 0.3; working properties, clay smooth and very fine-grained; drying conduct, satisfactory; water of plasticity, 38.6 percent; shrinkage



MAP OF SOUTHERN ALABAMA SHOWING LOCALITIES PROSPECTED FOR CLAY.

water, 21.0 percent; pore water, 17.6 percent; volume drying shrinkage based on dry volume, 33.6 percent; linear drying shrinkage based on dry length, 12.2 percent; dry strength, very good, and very dense; modulus of rupture not determined; firing behavior, pyrometric cone equivalent, 32.

Firing tests

Cone	Porosity (percent)	Firing shrinkage (percent)		Color
		Volume	Linear	
06	35.0	7.2	2.5	White.
04	31.8	12.5	4.4	Do.
02	28.5	16.2	5.7	Light cream.
2	22.0	22.5	8.1	Do.
4	21.5	23.4	8.4	Cream.
6	20.6	24.0	8.7	Do.
7	17.5	25.4	9.3	Do.
9	8.8	30.1	11.3	Gray, bluestoned.
11	5.2	31.7	12.0	Do.
13	.6	34.5	13.2	Dark gray, bluestoned.
15	12.2	29.0	10.8	Brown.

Conclusions: The clay is very plastic and very fine-grained. It has a high fusion point and should prove satisfactory as a refractory bond clay, or it could possibly be used as a ball clay. It has minimum porosity at cone 13 and slightly overfires at cone 15. If the kaolin is mined, this clay should prove to be valuable.

Chemical analyses of this kaolin from the Chalk Bluff area are quoted from an early publication[49] as follows:

	1	2		1	2
Silica	47.25	47.20	Magnesia	Trace	Trace
Alumina	36.50	37.76	Moisture	.50	Trace
Water	13.35	14.24			
Ferric oxide	2.56	Trace		100.16	99.20
Lime	Trace	Trace			

1. By H. Ries.
2. By W. B. Phillips.

The ceramic tests indicate that this is a good kaolin that may be of value for several purposes as suggested in the conclusions, and a considerable tonnage is evidently present. Because of the large gravel overburden and the general presence of a hard ironstone caprock immediately above the clay bed, the extent and continuity of the better quality clay could not be outlined by boring in the short time available. However, the testing indicates that, though this kaolin occurs at the same stratigraphic position over a large area, it does not extend continuously over all of this area. The data show that the thicker and better kaolin deposits are lenses that grade laterally into equivalent deposits of sandy kaolin, mottled clays, and even into sands.

[49] Ries, Heinrich, Clays of Alabama: Alabama Geol. Survey Bull. 6, p. 127, 1900.

The group of test holes 1 to 10 on the Thomas property, east of Camp Creek, indicate a considerable tonnage of the better kaolin here, though the distance it extends under the gravel overburden of the hillside was not determined. The hill rises rather steeply eastward from these test holes to an altitude about 90 feet higher, and this large gravel overburden would make open-pit mining of large quantities very difficult. Smaller quantities could be obtained by working along the outcrop without cutting deeply into the hillside, but for large operations it might prove more satisfactory to mine by tunneling into the hill. Such underground mining of ball clays is being done by the Kentucky Clay Mining Co., of Mayfield, Ky. The large amount of timber at hand would simplify the timbering operations, and these might prove less difficult than in the ball clays, which show so much more heaving and slipping during mining. The hard caprock might aid in the roof support, though all the clay could not be mined up to this caprock without causing excessive water seepage from the roof.

On the west side of Camp Creek there is also some kaolin of similar quality to that of sample 161–1, and hole 14, on the property held by J. C. Stovall, shows the presence of 10 feet of this kaolin at the same stratigraphic horizon, though this bed is dipping slightly westward in the area, as might be expected from the regional geology. Similar kaolin deposits might possibly be found on other properties in this region if sufficiently prospected at this same stratigraphic horizon, as a similar bed showing about 5 feet of kaolin was found on the Green & Mixon farm in sec. 1, T. 10 S., R. 13 W.

Shipping facilities are another serious consideration in any attempt to develop these kaolin deposits at Chalk Bluff, as the nearest railroad point is about 3 or 4 miles to the north, on the Illinois Central Railroad between Hackleburg and Lunsford. Truck haulage to the railroad would require some improvement of existing roads.

The chemical analyses and ceramic tests cited indicate that this clay may properly be classed as a kaolin, though microscopic examination of the material shows a minor part only of typical kaolinite, and a larger proportion of an isotropic clay that is perhaps a mixture of kaolinite and halloysite. In most natural exposures these kaolin beds obviously lie beneath Tuscaloosa gravel and above the harder sandstones of Pennsylvanian age; the kaolins have therefore been included with the Tuscaloosa, which carries some beds of clay. In good exposures along the new highway where the relations are more evident, it is clear that the clay is developed mainly below the contact of the Tuscaloosa and Pennsylvanian and in part as seams within the quartz sands and pebble beds of the older formation. However, the older formation near this contact is commonly as soft a rock as the overlying Tuscaloosa, owing to the leaching and weathering at this old surface. A check on these relations is found by microscopic examination of samples, which shows that the sand grains of the sandy kaolins consist almost entirely of quartz similar to the sands of the Pennsylvanian and are thus distinct from the highly feldspathic sands of the Tuscaloosa. It thus appears that these clays are a residual deposit formed at the old surface of the Pennsylvanian rocks, and that the kaolins are therefore residual and not sedimentary kaolins in the Tuscaloosa formation.

This evidence does not preclude the possibility that the clay was formed through the alteration and replacement of the Pennsylvanian

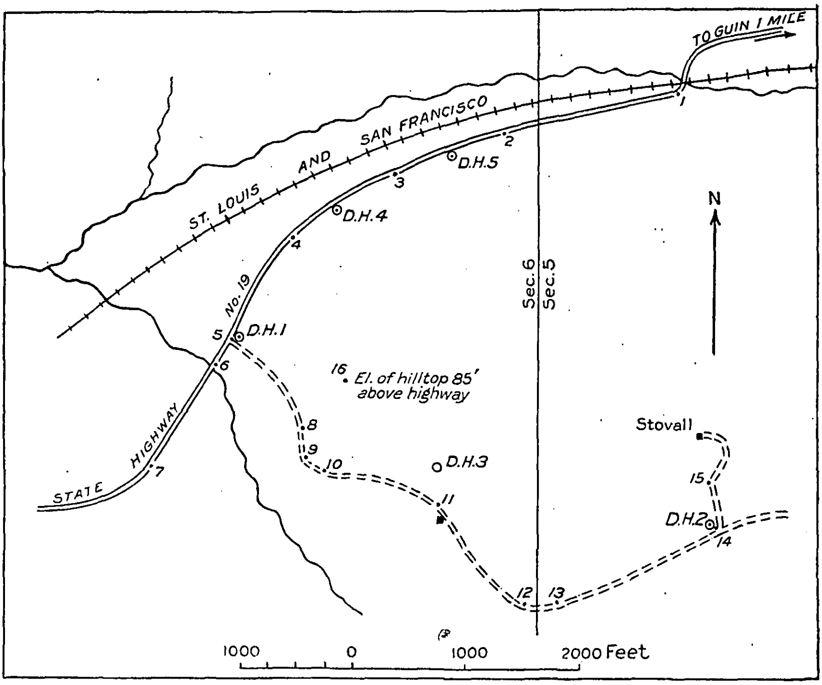


FIGURE 26.—Sketch map of Stovall property, Marion County, Ala., showing location of test holes. By H. S. Rankin.

sandstones by descending waters after the deposition of the Tuscaloosa formation. However, the suggestion that the alteration was pre-Tuscaloosa seems more probable, as there is no evidence that the process has affected lower parts of the Tuscaloosa formation, and the deposits occur only in the uppermost part of the Pennsylvanian rocks at the unconformable contact.

CLAY DEPOSITS NEAR GUIN

The clay deposits near Guin are largely confined to the same horizon as those of the Chalk Bluff area, at the Tuscaloosa-Pennsylvanian contact, but are of different character. They are more plastic and include deposits of possible value as plastic fire clays and pottery clays. The deposits on the J. C. Stovall property are indicated from the test holes shown in figure 26. The logs of these test holes follow:

Hole 1 (side of highway cut)

	Ft.	in.
Exposed above collar of drill hole:		
Sand	5	0
Sandy clay, gray	5	6
Clay, smooth, gray	1	0
Clay, black, carbonaceous	2	0
Section in drill hole:		
Clay, dark gray (no grit) sample 161-11	8	0
Clay, dark gray (some grit)	1	0
Clay, carbonaceous		6
At bottom on pebbly sandstone.	23	0

Hole 2

Surface sand	2	3
Clay, gray (some grit)		9
Clay, smooth, plastic, gray	1	0
Clay, smooth mottled red and gray	8	6
Clay, smooth, plastic, gray (sample 161-13)	4	6
	17	0

Hole 3

Exposed in cut:		
Clay, smooth, gray and mottled	2	0
Sandy clay, gray	7	0
Section in drill hole:		
Clay, smooth, brown gray	2	6
Clay, smooth, dark gray, partly carbonaceous	3	0
Sandy clay, gray, more sandy with depth	1	0
	15	6

Hole 4

Clay, smooth, gray	1	0
Sandy clay, white	10	0
Sand, hard, yellow	1	0
	12	0

Hole 5

Clay, smooth, mottled red and white	3	0
Sandy clay, white, more sandy with depth	8	0
	11	0

These deposits have a considerable thickness. They lie along and near State Highway 19, within a few hundred feet of the St. Louis–San Francisco Railroad line, and do not have a prohibitive amount of overburden near the outcrop. The ceramic tests on two of these samples follow:

Sample 161–11, Stovall property, hole 1, from collar of drill hole: Thickness, 8 to 10 feet; kind of clay, plastic fire clay; color, gray; fracture, hackly; screen tests not made; working properties, clay is plastic, slakes readily, and dries satisfactorily; drying conduct, good; water of plasticity, 45.9 percent; shrinkage water, 21.6 percent; pore water, 24.3 percent; volume drying shrinkage based on dry volume, 33.8 percent; linear drying shrinkage based on dry length, 12.6 percent; dry strength, very good; has the appearance of a stoneware clay; firing behavior, pyrometric cone equivalent, 30.

Firing tests

Cone	Porosity (percent)	Firing shrinkage (percent)		Color	Cone	Porosity (percent)	Firing shrinkage (percent)		Color
		Volume	Linear				Volume	Linear	
06	42.0	6.7	2.3	White.	7	26.9	21.6	7.8	White
04	40.5	9.6	3.3	Do.	9	24.5	22.2	8.0	Do.
02	37.3	13.8	4.8	Do.	11	21.8	23.1	8.4	Do.
2	36.2	16.6	5.9	Do.	13	15.6	28.7	10.7	Do.
4	34.4	17.8	6.1	Do.	15	1.6	37.2	14.4	Brown.
6	31.6	21.0	7.6	Do.					

Conclusions: The clay is a rather open burning clay, but when fired from cone 13 to cone 15, the shrinkage increases, and porosity decreases very markedly. The fired color is very light, and as the strength is good, it should be very satisfactory for a mixture with other clays for the manufacture of terra cotta. It could also be used for the manufacture of stoneware, but probably for the manufacture of dense ware a certain amount of a denser firing clay should be added to it. The clay should also prove satisfactory as a bond clay for refractories, as the fusion point is fairly high.

Sample 161–13, from adjacent outcrop equivalent to lower part of hole 2 from 12 to 16 ft. in hole, Stovall property: Kind of clay, plastic fire clay; color, gray; fracture, hackly; screen tests, small residue on each sieve; working properties, very good; drying conduct, good; water of pasticity, 46.5 percent; shrinkage water, 24.1 percent; pore water, 22.4 percent; volume drying shrinkage based on dry volume, 39.6 percent; linear drying shrinkage based on dry length, 15.4 percent; dry strength, good; firing behavior, pyrometric cone equivalent, 31.

Firing tests

Cone	Porosity (percent)	Firing shrinkage (percent)		Color	Cone	Porosity (percent)	Firing shrinkage (percent)		Color
		Volume	Linear				Volume	Linear	
06	40.1	7.3	2.5	White.	7	25.9	22.2	8.0	White
04	38.5	9.8	3.4	Do.	9	22.8	22.7	8.2	Do.
02	34.3	14.6	5.1	Do.	11	20.5	24.3	8.9	Do.
2	33.2	18.6	6.6	Do.	13	10.7	30.3	11.3	Gray, blue-stoned.
4	31.2	19.8	7.1	Do.					
6	27.9	21.5	7.8	Do.	15	1.5	36.6	14.0	Brown.

Conclusions: This is a rather open burning clay and has fairly good dry strength. It should prove valuable as an ingredient for terra cotta bodies or as a bond clay for refractories.

OTHER CLAY DEPOSITS IN MARION COUNTY

Some of the more promising of the many additional clay deposits in Marion County were investigated without very encouraging results, and maps of their exact location and logs of the test holes are therefore not included in this report. A more detailed investigation would doubtless have discovered additional deposits.

A bed of kaolin occurs at the Pennsylvanian-Tuscaloosa contact a quarter of a mile south of Pearces Mills, on the old Gillon place. Boring showed the bed to be 7 feet thick at one place but much thinner nearby, and the clay was very sandy. No sample was taken for ceramic testing, but it appeared to be similar to the sandy kaolin at hole 11 of the Chalk Bluff area.

Another bed of kaolin occurs at this same stratigraphic position in the northwestern part of the county, in sec. 5, T. 9 S., R. 14 W. An old pit about 1,500 feet northwest and upstream from the old Armstrong house shows 3 feet of good kaolin exposed, and boring there gave the following section:

Hole 1 (in old pit)

	Ft.	in.
Exposed above collar of drill hole:		
Kaolin, cream-colored to white (sample 161–6)	3	0
Section in drill hole:		
Kaolin, hard, smooth, cream-colored	2	0
Kaolin, hard, mottled red and white		6
Kaolin, smooth, cream-colored	2	6
Clay, hard, mottled red and white	10	0
Sandy clay, mottled	3	0
	21	0

A sample of this kaolin was tested, and the results are given below.

Sample 161–6, hole 1, sec. 5, T. 9 S., R. 14 W.: Thickness, 8 feet of good kaolin interbedded with colored kaolin; kind of clay, kaolin; color, light cream with some iron stains; fracture, conchoidal; screen tests not made on account of non-slaking properties; very little grit; working properties, material is sufficiently plastic to be readily molded; working properties depend on the fineness of grinding; larger particles of clay do not slake readily, even in hot water; drying conduct, good; water of plasticity, 31.5 percent; shrinkage water, 5.9 percent; pore water, 25.9 percent; volume drying shrinkage based on dry volume, 7.8 percent; linear drying shrinkage based on dry length, 2.7 percent; dry strength, very poor; firing behavior, pyrometric cone equivalent, above 33.

Firing tests

Cone	Porosity (percent)	Firing shrinkage (percent)		Color
		Volume	Linear	
06	44.7	14.2	5.0	All bars white with a slight yellow tinge.
04	43.6	17.0	6.0	
02	43.2	17.2	6.1	
2	42.2	18.8	6.7	
4	41.1	20.1	7.2	
6	40.1	20.8	7.5	
7	37.6	23.8	8.7	
9	33.8	29.5	11.0	
11	29.3	33.7	12.8	
13	29.3	33.6	12.8	
15	27.2	35.8	13.7	

Conclusions: The clay has an exceptionally high fusion point. It does not have marked bonding properties, but they may be improved by fine grinding. The firing shrinkage is high, and it is probable that precalcination for part of the clay would be necessary for its use in the manufacture of refractories. The most probable use for this material would be in the manufacture of high-grade kaolin refractories.

However, additional drilling of twelve test holes showed that the good kaolin deposit is very small, as borings about 100 feet upstream and downstream from the old pit showed only the red and mottled clays. The brick-red kaolinitic clay is extensively developed here, but the iron content is obviously far too high to make such clay of value for ordinary usage. A sketch map of the location of the test holes is therefore not presented in this report.

An occurrence of kaolin on the Dan Homer place, on the road from Guin to Pearces Mills, in sec. 6, T. 12 S., R. 12 W., proved to be only 2 feet thick where prospected in a ravine, though it is perhaps thicker elsewhere, but the 20 to 30 feet of gravel overburden made it difficult to attempt any additional prospecting. The fusion point of this clay is above cone 33, but additional tests were not made because the deposit was apparently small. This clay differs from the previously described deposits in Marion County in being a true sedimentary kaolin within the Tuscaloosa formation, though near its base, and the sedimentary origin is evident in the fine though indistinct bedding lamination.

Large amounts of clay at the Pennsylvanian-Tuscaloosa contact are exposed along United States Highway 78 between Guin and Hamilton, and large slips and slumping on these clay beds have caused considerable trouble in constructing and maintaining the highway where it cuts into the hillsides. Most of these thick deposits of plastic clay are mottled red, purple, and dark gray and contain too much iron to be of value except perhaps for low-grade stoneware. A boring into these mottled clays at an exposure along the highway in the northern part of sec. 6, T. 11 S., R. 14 W., penetrated 20 feet into the clay without reaching its base, but its appearance did not seem to warrant ceramic testing. Another boring in clay of this same type was made along this highway near the northwest corner of sec. 23, T. 11 S., R. 14 W., 150 feet south of the highway post marked "542—78.5 PT," and gave the following section:

	Ft.	in.
Clay, smooth, plastic, mottled red and yellow	7	0
Clay, hard, smooth, light gray (sample 161–14)	2	6
Clay, smooth, yellow	2	6
Sandy clay, white; lower part mostly sand	3	0
	15	0

Sample 161–14 showed a fusion point above cone 33, which is exceptionally high for clay of this type. The clay is plastic and should prove very satisfactory as a source of bond clay for refractories or for use in the manufacture of terra cotta. It is possible that additional drilling in the immediate vicinity might outline considerable amounts of this better-grade clay, though most of it is the mottled red and purple variety.

CLAYS IN MOBILE AND BALDWIN COUNTIES

In Mobile and Baldwin Counties numerous clay beds are exposed, most of which are very sandy and suitable only for brick clay. These clays occur near the surface in a sandy formation, probably to be classed with the Citronelle formation (Pliocene), with more extensive but poorer clays in the underlying Hattiesburg clay (Miocene). Some of the clay beds in the Citronelle formation are white sedimentary kaolin but are very sandy and generally are more nearly white clayey sand. One of these deposits of white, sandy kaolin that appeared to be of a better grade and less sandy than the average was tested by borings. This occurrence is at the old Bonashek clay pit, in the SW¼ sec. 3, T. 7 S., R. 3 E., southwest of Summerdale, in Baldwin County. The ceramic tests on sample 161–23 and a log of the test hole at the north end of the old pit follow:

		Ft.	in.
Sand		3	6
Sand, yellow, and clay		3	0
Kaolin, white (slightly sandy)	(sample 161–23).	3	0
Sandy kaolin, white	(sample 161–23).	2	6
Clay, dark red		1	0
		13	0

Hard ferruginous seam.

Thickness, 5½ feet; kind of clay, sedimentary kaolin; color, very light gray; fracture, earthy; screen tests, percent on 115 mesh 0.7, on 150 mesh 0.6 (residues mica and quartz), on 200 mesh 2.0; working properties, good; clay slakes readily; drying conduct, good; water of plasticity, 34.0 percent; shrinkage water, 17.4

percent; pore water, 16.6 percent; volume drying shrinkage based on dry volume, 31.8 percent; linear drying shrinkage based on dry length, 12.0 percent; dry strength, rather weak. The clay was lawned and washed through a 115-mesh sieve before making bars for testing the drying and firing behavior. Firing behavior, pyrometric cone equivalent, 30.

Firing tests

Cone	Porosity (percent)	Firing shrinkage (percent)		Color
		Volume	Linear	
06	35.0	2.3	0.7	Light cream.
04	33.0	4.0	1.4	Do.
02	29.9	7.6	2.6	Do.
2	28.8	9.7	3.4	Do.
4	27.8	9.5	3.3	Do.
6	26.9	10.1	3.5	Do.
7	25.8	11.9	4.1	Do.
9	19.3	16.1	5.7	Do.
11	10.1	20.9	7.5	Light gray with bluestoning.
13	3.9	22.7	8.2	Gray, bluestoned.
15	3.8	22.0	8.0	Brown.

Conclusions: The clay seems to be slightly siliceous. It has a good firing behavior with gradual vitrification, although tends to overfire at cone 15. This clay should be useful as an ingredient of white-ware bodies, where a pure-white ware is not desired. It should be washed before use.

Five additional test holes within a few hundred feet of the old Bonashek pit indicate that the bed is rather extensive but variable in thickness and amount of sand. Similar deposits may be common in this area, but they could be found only by considerable boring, as exposures of the bedrock in this flat country are very uncommon. Some additional occurrences of clay were inspected but did not appear of sufficient size or quality to warrant testing. One such deposit was in the northern part of the town of Citronelle, in Mobile County, but this deposit was very sandy, and would properly be classed as a white kaolinic sand of little value.

CLAYS IN BIBB AND TALLADEGA COUNTIES

Most of the clay deposits of Bibb and Talladega Counties are of the fire-clay class, including both sedimentary plastic fire clays and residual fire clays. The plastic fire clays are in the lower part of the Tuscaloosa (Upper Cretaceous) formation, and several such deposits lie in the area about Woodstock, in the northern part of Bibb County. Some of this clay was formerly used in making fire brick at Bessemer and Birmingham. However, these clays are local pockets of very slight extent that have been uncovered through excavations for the brown iron ore with which the clays are associated, and this mode of occurrence made it difficult to attempt any additional prospecting for such clays by the boring methods employed in this project.

In Talladega County numerous deposits of residual sandy clays might be utilized for fire brick, but though rather refractory clays, they are not plastic and not generally of the best quality. These residual clay deposits have resulted from the weathering of the Cambrian and Ordovician dolomites of the region and are therefore surficial deposits with little or no overburden. One such deposit just north of the Louisville & Nashville Railroad at Silver Run siding, northeast of Munford, was formerly mined for fire brick. This deposit is at the surface and requires no stripping, but it is a thin bed, and the borings indicate that the remaining clay is generally only 1 to 2 feet thick, the thicker part of the deposit having been worked out. The location of these test holes and their logs are therefore not included here, though similar deposits of larger size could probably be located in this area if needed.

A residual clay was prospected on the W. J. Bell property, 4 miles northeast of Munford, in sec. 11, T. 17 S., R. 7 E. A preliminary ceramic test on a sample of the white clay from this locality had indicated some peculiar properties that might make it a valuable clay, but the amount of the white clay free from the heavily iron-stained clay is small. For purposes that would not require a white clay, as in refractory brick, a considerable amount of this clay might be obtained, as a thickness of 14 feet was found in a test hole at the old prospect pit.

However, some additional test holes indicate that the deposit is very pockety, and intensive testing would be necessary to outline any large tonnage.

Large quantities of a sandy residual clay that might serve for fire brick occur in various localities to the east of Alpine, in Talladega County, but it appears to be of a rather poor grade in general, and was therefore not tested in this work.

CLAYS IN DE KALB COUNTY

A variety of residual clays occur in De Kalb County, and some of these have been rather extensively worked in the past. The two main modes of occurrence are as residual pockets in the Cambrian and Ordovician dolomites and as seams interbedded with the Fort Payne (Mississippian) chert. Along the ridge of Red Mountain, both northeast and southwest of Valley Head, there are a number of old pits and shafts in some high-grade clays in the Fort Payne chert. Some of these old operations are reported in Bulletin 6 of the Geological Survey of Alabama. A large amount of such clay apparently remains, but most of it is so intimately mixed with the chert beds that it would be difficult to mine and handle; and because of the hard chert beds it was impossible to prospect such deposits by boring.

These deposits include kaolins, halloysite, and very siliceous clays that grade into tripoli.

The residual clay deposits in this county include a large surface deposit in the valley flats around High Point siding, on the Alabama Great Southern Railroad just northeast of Valley Head. Test holes into this deposit commonly went through thicknesses of about 15 feet, with one hole penetrating 28 feet into the clay. The 13 test holes were spread over an area about 1,000 feet wide by 3,500 feet long on both sides of the railroad, above and below High Point. This indicates the presence of a very large tonnage of the clay, with little or no overburden. From field appearance the clay seemed to be of possible value as a refractory clay for fire brick. The sample tested, however, proved to be of very poor quality, with a fusion point below cone 26 and firing to a brown color. The field data on the prospecting are therefore not presented here.

The residual clay deposits in pockets in the Cambrian and Ordovician dolomites are numerous, but only a few were investigated. The old Browder pit, owned by F. E. Ladd, is 4.6 miles northwest of Fort Payne, in the SE¼NW¼ sec. 30, T. 6 S., R. 9 E. Drill hole 1 in the south end of this pit penetrated the following section:

	Feet
Clay, white	8
Clay, mottled white and pink	7
Clay, white with blue-gray tone	6
Sandy clay, yellow and white	2
Sandy clay, purple	2
Sand, yellow, and rock fragments	1
	26

Hole 2 (north end of pit, 300 feet north of hole 1)

Exposed above collar of drill hole:	
Sandy clay and sand	2
Clay, smooth, white	2
Section in drill hole:	
Clay, white	4
Clay, red mottled, with some sand	4½
Clay, red mottled, slightly sandy	3½
Clay, white	3
Sandy clay, red and yellow	3
	22

Hole 4 (between holes 1 and 2, about 150 feet north of hole 1)

Clay, white	10
Sandy clay, light brown	2
Clay, firm, bluish white	16½
	28½

These test holes indicate that owing to the thickness of the clay bed, a considerable tonnage of clay remains in this deposit, and ceramic tests on a composite sample (161–20) from the upper 21 feet of hole 1 are presented below.

Kind of clay, siliceous fire clay; color, gray with iron stains; fracture, hackly; screen tests, percent on 115 mesh, 0.7, on 150 mesh 0.5, on 200 mesh 0.5; origin, probably resulted from the weathering of cherty dolomite; working properties, good; drying conduct, good; water of plasticity, 35.7 percent; shrinkage water, 19.0 percent; pore water, 16.7 percent; volume drying shrinkage based on dry volume, 33.3 percent; linear drying shrinkage, 12.0 percent; dry strength, bars rather weak; firing behavior, pyrometric cone equivalent, 30.

Firing tests

Cone	Porosity (percent)	Firing shrinkage (percent)		Color
		Volume	Linear	
06	37.0	2.7	0.9	White.
04	34.5	7.0	2.4	Do.
02	31.4	9.8	3.4	Do.
2	29.7	12.5	4.4	Do.
4	27.5	15.6	5.5	Do.
6	25.5	15.9	5.6	Do.
7	24.6	17.5	6.2	Do.
9	17.5	21.6	7.8	Light gray.
11	13.0	24.1	8.8	Do.
13	5.6	27.8	10.3	Gray and bluestoned.
15	1.1	29.8	11.1	Do.

Conclusions: The clay has a fusion point of cone 30, which is not particularly high. The dry strength is not great, and consequently it cannot be rated as highly refractory bond clay. It can be considered as a rather open burning plastic clay. As the evidence indicates the presence of a considerable amount of this clay, it may be useful as an addition in certain rather siliceous refractories where load bearing at moderately high temperatures is desirable. The fired test pieces, after wetting, show a green discoloration.

This clay has been reported to show the bleaching properties of a fuller's earth, and a sample was therefore tested as a bleaching agent for mineral oil by P. G. Nutting. This test indicated that it is less efficient than the lowest grades of commercial bleaching clay and considerably below the best fuller's earth.

A test hole drilled in the bauxite pit formerly operated by the Consolidated Mining Co. in sec. 10, T. 6 S., R. 9 E., showed the following section:

	Feet
Clay, white, bauxitic (sample 161–21)	11
Clay, light grayish-white (more plastic than above)	10
Sandy clay, mottled yellow, and chert fragments	1
	22

Ceramic tests on sample 161–21 are tabulated on the following page and show the properties characteristic of such bauxitic clays:

Kind of clay, fire clay; color, white; fracture, earthy; screen tests, trace on 115 150, and 200 mesh; working properties, fairly plastic; drying conduct, good; water of plasticity, 37.9 percent; shrinkage water, 8.6 percent; pore water, 28.4 percent; volume drying shrinkage based on dry volume, 12.4 percent; linear drying shrinkage based on dry length, 4.5 percent; dry strength, poor; firing behavior, pyrometric cone equivalent, above 33.

Firing tests

Cone	Porosity (percent)	Firing shrinkage (percent)		Color
		Volume	Linear	
06	47.6	14.1	4.9	White with slightly yellow tint throughout the firing range.
04	47.3	14.3	5.0	
02	47.3	14.7	5.2	
2	46.4	16.3	5.8	
4	44.0	19.7	7.1	
6	43.3	20.2	7.3	
7	40.3	24.1	8.8	
9	33.7	31.6	11.9	
11	30.3	35.4	13.6	
13	29.2	37.2	14.4	
15	25.1	39.8	15.6	

Conclusions: The clay has an exceptionally high fusion point but little or no bonding property. It is an extremely open burning clay and has little fired strength in the above-stated range of experimental firings. The firing shrinkage is very high, and it is evident that shrinkage is not complete at cone 15, as can be judged from the porosity. It can probably be used in small amounts in refractories, but calcining at high temperatures is suggested before it is introduced into refractories. As the clay is very friable, considerable difficulty would be encountered in the ordinary methods of calcining used in commercial practice.

This deposit of clay appears to be a pocket of very small areal extent, in the Cambrian and Ordovician dolomites, but is of considerable thickness. No attempt was made to outline the tonnage present by drilling, because the value of such bauxitic clays is not great at present, owing to their large shrinkage in firing.

CHAPTER 7.—BLEACHING CLAYS IN ALABAMA

By M. N. BRAMLETTE, H. X. BAY, and A. C. MUNYAN

INTRODUCTION

By G. R. MANSFIELD

Three separate investigations of bleaching clays were undertaken in Alabama. The first, in charge of M. N. Bramlette in the spring of 1934, was a study of the Sucarnoochee (Porters Creek) clay as a source of fuller's earth or natural bleaching clay, but as this work appeared unpromising, he turned to the investigation of the ceramic clays described in the preceding chapter. The second was a search by H. X. Bay for the continuation into Alabama of the promising bleaching clays of Mississippi.[50] This work was done in the fall of 1934. The third was an examination by Arthur C. Munyan, under a later allotment of funds, of formations and localities not studied in the two earlier investigations. This work was done in the spring of 1935.

Scope and results of investigation.—The work was chiefly a reconnaissance to find the more promising beds of bleaching clays, to collect samples for testing, and to lay the foundation for possible further detailed studies. Exposures in road and stream cuts were examined wherever practicable, and these observations were supplemented by borings with a 3-inch Iwan auger with sufficient lengths of ¾-inch pipe to reach depths of 30 feet. Two men were employed for this purpose.

The results obtained were rather disappointing, for no deposits of outstanding commercial value were recognized, though some would no doubt warrant more extended investigation.

Acknowledgments.—All samples collected were tested in the laboratory of the Geological Survey in Washington under the direction of P. G. Nutting, whose methods are described on pp. 13–15. L. W. Stephenson and C. W. Cooke, of the Survey, visited the field at different times and rendered counsel and aid in stratigraphic problems.

POSSIBILITY OF FULLER'S EARTH IN THE SUCARNOOCHEE (PORTERS CREEK) CLAY

By M. N. BRAMLETTE

The Porters Creek formation is being mined at Olmstead, Ill., by the Sinclair Oil Co. and the Standard Oil Co. of Indiana. It has not

[50] Bay, H. X., A preliminary investigation of the bleaching clays of Mississippi: Mississippi Geol. Survey Bull. 29, 1935.

proved an ideal bleaching agent but is efficient enough to be of commercial importance because of the large tonnage available and its accessibility. The extension of the formation from Illinois into western Kentucky and Tennessee was studied by parties under the supervision of the writer, concurrently with the work in Alabama, which was in immediate charge of H. S. Rankin. The results obtained in Kentucky and Tennessee are described on pp. 190–195.

Occurrence and character of the formation.—The Porters Creek is a distinctive clay formation of the Midway group (lower Eocene) that extends as a continuous and mappable unit from Alabama into Mississippi, western Tennessee, western Kentucky, southern Illinois, and Missouri. In Alabama it has been called the Sucarnoochee clay, but it is clearly continuous with the Porters Creek clay of adjacent States. In western Alabama this formation shows its typical character as a dark clay that weathers to a light-buff or dove color, with a hackly to conchoidal fracture. It is a marine formation, and in Alabama the writer collected at several horizons some Foraminifera which, according to L. G. Henbest, of the United States Geological Survey, are of Midway age. This determination substantiates the age relations previously deduced from the small fauna of larger fossils and from stratigraphic relations. Eastward from Sumter County the formation becomes increasingly sandy, and near the center of the State it seems to grade into a sandstone. From the width of the outcrop in Sumter County the formation appears to be several hundred feet in thickness, but as no satisfactory measurements of the regional dip here are available, a good estimate of thickness is not possible.

The chemical and petrographic characteristics of the formation are discussed in the chapter on Tennessee and Kentucky (pp. 190–195). From the field and microscopic examinations the formation in Alabama appears to consist dominantly of ordinary clastic clay and silt, with a lesser and somewhat doubtful proportion of admixed bentonitic clay. The sandy clays and the sands into which the formation grades eastward in Alabama appear to be ordinary clastic sands. The sandstone dikes that are so common in this formation in Tennessee were not observed in Alabama.

As a result of its composition and physical character, this clay shows bleaching properties, but of varying degree at different localities and at different stratigraphic horizons within the formation. Most of it shows little or no activation or improvement of bleaching power by acid treatment, a behavior characteristic of most fuller's earths. Other samples, having low natural bleaching power, show some improvement with acid treatment, but none of the Sucarnoochee clay samples show sufficient improvement with such processing to place them in a class with some of the best bentonites as activable bleaching clay.

Location of samples collected.—The general location of the series of samples collected between Livingston and York, along U. S. Highway 11 in Sumter County, is indicated on figure 24 and plate 6. These samples were taken from outcrop exposures and intermediate test-hole borings across the strike of the Sucarnoochee clay. The sampling was begun at the base of the formation, at an outcrop of the contact with the underlying Selma (Upper Cretaceous) chalk, just south of the bridge across Sucarnoochee Creek 0.7 mile south of Livingston. The sampling was continued at intervals along the highway to the top of the formation, at its contact with the basal glauconitic sands of the Naheola formation, in a highway cut 2.25 miles southwest of the Alabama, Tennessee & Northern Railroad crossing in York. A profile from altitudes along this highway was drawn in order to determine the position of the outcrop samples in the stratigraphic section and to locate test holes for additional samples where the clay was not exposed. This profile and the more exact locations are not presented, because none of the samples appear from the following tests to be of commercial value. A total of 57 samples were taken, 20 from outcrops and 37 from the series of 19 test holes. Of these samples 23 representing intervals of 10 to 20 feet throughout the formation were selected for testing their bleaching properties. It was planned to test additional samples within any intervals that might appear from these samples first tested to be more favorable.

The oil bleaching tests on sample A–1, from the base of the formation, up to sample A–23, at the stratigraphic top, are presented in the following table:

Bleach ratings of samples of Sucarnoochee clay, Sumter County, Alabama

Sample No.	Raw				Acid-treated				Acid-soluble			
	G	Y	R	B	G	Y	R	B	Fe	Al	Ca	Off (percent)
A-1	0.5	0.6	0.6	0.6	1.5	1.9	2.0	2.0	6	4	Tr.	25
A-2	.5	.7	.7	.7	1.4	2.1	2.2	2.3	6	4	Tr.	30
A-3	.6	.7	.7	.7	1.3	1.9	2.0	2.0	6	4	Tr.	30
A-4	.6	.7	.7	.7	1.2	1.9	2.0	2.1	6	4	Tr.	25
A-5	.6	.7	.7	.7	1.4	2.0	2.2	2.2	6	4	Tr.	30
A-6	.6	.7	.7	.7	1.4	1.8	1.9	2.0	5	5	Tr.	25
A-7	.5	.6	.7	.7	1.3	1.9	2.0	2.0	6	4	Tr.	25
A-8	.6	.7	.7	.7	1.2	1.7	1.8	1.9	6	4	Tr.	25
A-9	.5	.6	.6	.6	1.2	1.8	1.9	1.9	6	4	Tr.	25
A-10	.7	.8	.9	.9	1.2	1.8	1.9	1.9	6	4	Tr.	25
A-11	.7	.7	.8	.8	.7	1.2	1.3	1.4	6	4	Tr.	30
A-12	.6	.7	.7	.7	1.0	1.4	1.5	1.5	6	4	Tr.	25
A-13	.5	.6	.6	.6	1.1	1.6	1.7	1.7	6	4	Tr.	25
A-14	.6	.7	.7	.7	1.2	1.8	1.9	1.9	6	4	Tr.	25
A-15	.5	.6	.7	.7	1.2	1.7	1.8	1.8	6	4	Tr.	25
A-16	.5	.6	.6	.6	1.1	1.4	1.5	1.5	6	4	Tr.	25
A-17	.7	.8	.9	.9	1.1	1.4	1.5	1.6	7	3	Tr.	30
A-18	.6	.7	.7	.7	1.2	1.5	1.6	1.7	6	4	Tr.	25
A-19	.6	.7	.7	.8	1.0	1.4	1.5	1.5	6	4	Tr.	25
A-20	.6	.7	.8	.8	1.1	1.6	1.6	1.6	6	4	Tr.	25
A-21	.5	.6	.6	.6	1.1	1.6	1.6	1.6	6	4	Tr.	25
A-22	.6	.7	.7	.8	1.1	1.4	1.5	1.5	6	4	Tr.	25
A-23	.5	.6	.7	.7	1.0	1.4	1.6	1.6	7	3	Tr.	30

The bleach ratings given above may be compared with those of the commercial and high-grade clays listed on p. 15.

Conclusions: These results indicate that the Sucarnoochee (Porters Creek) clay in this region has some bleaching power, as it has generally in other regions. However, this clay does not appear as good a natural bleaching clay as parts of the same formation in western Tennessee and southern Illinois, and it is distinctly inferior to the best fuller's earths. The clay in Alabama shows a greater increase in bleaching efficiency with acid treatment, particularly that in the lowest part of the formation, than the same clay from Illinois and Tennessee. When thus activated, however, it does not compare in efficiency with some of the activable bentonites. The value of the Sucarnoochee (Porters Creek) clay for bleaching vegetable oils, such as cottonseed oil, was not tested, as it is known to be less efficient than the clays from Creede, Colo., and Macon, Ga. It would thus appear that this extensive deposit of clay in Alabama is not of economic interest as a bleaching clay.

BLEACHING CLAYS IN CLARKE AND CHOCTAW COUNTIES

By Harry X. Bay

OCCURRENCE

Bleaching clays have been recognized at three geologic horizons in Clarke and Choctaw Counties, Ala. From oldest to youngest these are (1) the Tallahatta formation, (2) the Lisbon formation, and (3) the Jackson formation. The character of these formations varies greatly, and the beds are only locally high enough in bleaching power to be worthy of note. The locations of the different deposits examined are shown on plate 6.

The Tallahatta formation locally contains beds of both naturally active and activable clay. A sample of Tallahatta white claystone from White Bluff, on the Tombigbee River 1.9 miles northeast of Cunningham, in Clarke County, described below, proved to be a commercially low-grade naturally active material. Tallahatta clay that is rather highly activable crops out in 2- to 6-inch beds along State Highway 29, about 7 miles north of Gilbertown, in Choctaw County.

Certain beds of Lisbon clay are apparently bentonitic and in some places sufficiently activable to be of commercial interest. The best activable clay found in Clarke County was found in sec. 35, T. 8 N., R. 4 E. Samples of good activable bleaching clay were collected from the Lisbon formation in sec. 22, T. 11 N., R. 3 W.; sec. 20, T. 9 N., R. 3 W.; and sec. 3, T. 9 N., R. 4 W. The Lisbon clay deposits are highly variable in bleaching properties and are known to change distinctly within short distances, both vertically and laterally. It is doubtful if there are deposits within the Lisbon formation that will provide sufficient bleaching clay of commercial grade to justify mining activity.

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Although apparently bentonitic in character and widespread in its occurrence, the Jackson clay in Clarke and Choctaw Counties does not appear activable enough to be of commercial interest. The Jackson "subbentonite" (so called because it is a clay having some of the physical properties of bentonite) is very similar to that which occurs directly to the west, in the northern part of Wayne County, Miss., and it very probably occupies the same stratigraphic position.

CLARKE COUNTY DEPOSITS

TALLAHATTA FORMATION

Thick sections of the Tallahatta formation are exposed in the bluffs bordering the Tombigbee River in Clarke County, Ala. In an excellent exposure at White Bluff, 1.9 miles northeast of Cunningham, thick beds of indurated white claystone crop out in the river bluff.

Various attempts have been made to operate a bleaching-clay mine at White Bluff during the last 10 years. It is reported that the latest mining was done in 1933. The operations have always been on a small scale, and only relatively small amounts of clay have been removed. Mining has been confined to the upper 10 or 15 feet of the formation, and the material shipped consists of white, light and porous claystone. This indurated clay is highly jointed, and the planes of separation are coated with red and yellow ferruginous stain.

A sample from the mine face which appeared to be typical of the material mined yielded the following bleach rating:

Raw				Acid-treated			
G	Y	R	B	G	Y	R	B
0.9	1.1	1.2	1.3	0.6	0.7	0.8	1.0

This sample is a low-grade fuller's earth, somewhat lower in bleaching power than most of the clays that supply the present markets. The material granulates well; a characteristic which is a prerequisite for clays used in the percolation process of oil bleaching.

White Bluff is some distance from railway facilities, but it borders the Tombigbee River, which is navigable as far as this site. Mined clay could be chuted from the high bluff to barges on the river below for shipping.

From the meager data at hand it is thought that the Tallahatta claystone bed at White Bluff offers doubtful commercial possibilities, and a thorough study of the deposit should be made before any mining operations are attempted.

LISBON FORMATION

The Lisbon formation crops out along the north and south flanks of the Hatchetigbee anticline in Clarke County. The northern belt of outcrop extends in a northwesterly direction across the central part of the county, and the southern outcrop is limited to a narrow strip that traverses Tp . 7, 8, and 9 N., R. 1 E. and the west-central part of T. 9 N., R. 1 W.

Clays that appear to be bentonitic are known in the Lisbon formation in T 9 N., R. 1 W., and T. 8 N., R. 4 E., in Clarke County. For the most part these deposits are of no commercial interest.

T. 9 N., R. 1. W.—No commercially activable or naturally active clays were encountered in T. 9 N., R. 1 W., but noncommercial clays of the activable type are common. Typical occurrences are described below.

Section of Lisbon formation in road cut in the SE¼NW¼ sec. 5, T. 9 N., R. 1 W., Clarke County, Ala., just south of Ulkinask Creek

	Feet
3. Sand, red and brown, medium-grained, pebbly	20
2. Clay, greenish gray, hard and brittle, waxy, bentonitic (?) Lower portion interlaminated with fine sand	9
1. Sand, greenish gray to brown, medium-grained, glauconitic.	

A sample taken 2 feet from the top of bed 2 yielded the following bleaching rating:

Raw				Acid-treated			
G	Y	R	B	G	Y	R	B
0.5	0.6	0.6	0.7	1.0	1.3	1.7	1.8

Although this clay is somewhat activable (perhaps indicating a bentonitic character) it is not of commercial interest.

An auger hole bored some 200 yards to the east of this exposure, on the property of Mrs. T. A. Coate, shows the varied character of this bentonitic (?) zone:

Section in auger hole on farm of Mrs. T. A. Coate, sec. 5, T. 9 N., R. 1 W., Clarke County

	Feet
5. Sand, mottled green and brown, fine-grained	3
4. Clay, greenish gray, sandy, bentonitic (?), interlaminated with fine sand	1½
3. Clay, mottled greenish gray and brown, slightly sandy and micaceous, somewhat calcareous, brittle, waxy, bentonitic (?)	3½
2. Like bed 3 but nonmicaceous and more sandy	1
1. Shale, dark blue, fossiliferous, micaceous, calcareous, silty.	

Samples selected from the middle portions of beds 2, 3, and 4 gave the following bleach ratings:

Bed	Raw				Acid-treated			
	G	Y	R	B	G	Y	R	B
4	0.3	0.4	0.4	0.4	0.6	0.9	1.1	1.2
3	.4	.5	.5	.5	1.2	1.7	1.9	2.0
2	.4	.5	.5	.5	.7	1.0	1.2	1.4

Bed 3, the least sandy bed of the section, is the most activable, but it is not up to commercial requirements.

A small deposit (about 2 acres) of low-grade activable clay was found on the farm of John York, in the SE¼SW¼ sec. 5, T. 9. N., R. 1 W. This bed crops out in a road cut that reveals 3½ feet of mottled greenish-gray and brown, slightly micaceous, somewhat sandy, hard and brittle clay. The deposit is covered by thick pebbly sand. A sample from the middle of the exposure gave the following bleach rating:

Raw				Acid-treated			
G	Y	R	B	G	Y	R	B
0.2	0.3	0.3	0.3	1.0	1.1	1.1	1.1

After acid treatment this material gives a fair water-white bleaching test, but it shows practically no color separation. The deposit is of no commercial interest.

A rather extensive deposit of low-grade clay of the activable type occurs on the properties of Gail Robinson and J. Carl in the SE¼NE¼ sec. 8, T. 9 N., R. 1 W.

By means of several bore holes the nature of the clay bed was determined, and the following generalized section is typical of the deposit:

	Feet
5. Sand, red, pebbly, coarse-grained	5
4. Clay, mottled red and gray, plastic, arenaceous	5
3. Clay, greenish gray to brown, hard and brittle, unctuous, bentonitic, with interlaminated white fine-grained sand	3
2. Like bed 3 but bluish gray and less sandy	4
1. Clay, brownish-gray to blue, fossiliferous, sandy, micaceous, bears occasional small white calcareous nodules.	

The bleach ratings of representative samples from beds 3, 2, and 1 are given on the following page.

Bed	Raw				Acid-treated			
	G	Y	R	B	G	Y	R	B
3	0.4	0.5	0.5	0.5	1.1	1.7	1.8	1.9
	.3	.4	.5	.5	.7	.9	1.1	1.2
	.2	.4	.4	.4	1.2	1.6	1.8	1.8
	.2	.2	.3	.3	1.2	1.3	1.3	1.3
2	.4	.4	.4	.4	1.1	1.6	1.6	1.6
	.5	.5	.5	.5	1.2	1.6	1.8	1.8
	.2	.3	.3	.3	1.2	1.3	1.3	1.3
	.4	.4	.5	.6	1.1	1.4	1.7	1.9
1	.2	.3	.3	.3	1.1	1.2	1.4	1.4

The clay in this deposit is not sufficiently activable to be of commercial interest.

Several occurrences of subbentonite were noted in the vicinity of the village of Coffeeville. The bed ranges from 2 to 9 feet in thickness and consists of greenish-gray hard and brittle, somewhat sandy, slightly micaceous, unctuous bentonitic (?) clay. The lower part of the stratum is usually calareous and is locally fossiliferous. The bed is highly jointed and the planes of separation are in many places coated with a black manganiferous stain.

Bleach ratings of a group of representative samples of subbentonites from the Coffeeville area are given below.

Sample No.	Raw				Acid-treated			
	G	Y	R	B	G	Y	R	B
1	0.2	0.3	0.3	0.3	1.2	1.4	1.4	1.4
2	.2	.2	.3	.3	1.0	1.5	2.0	2.2
3	.2	.3	.3	.3	.9	1.1	1.3	1.4
4	.2	.3	.3	.3	1.1	1.7	1.9	2.1
5	.2	.3	.3	.3	1.2	1.3	1.3	1.3
6	.4	.4	.4	.4	1.0	1.6	1.8	1.8
7	.2	.3	.3	.3	1.1	1.1	1.2	1.3
8	.1	.2	.2	.2	1.0	1.2	1.2	1.2
9	.2	.3	.3	.3	1.1	1.6	1.9	2.0

1, 2, and 3 from auger holes in the NE¼ SE¼SE¼ sec. 9; 4 and 5 from auger holes in the SE¼SE¼SE¼ sec. 9; 6, 7, and 8 from auger holes in the NE¼NW¼ sec. 16; 9 from an exposure in the NE¼NE¼NW¼ sec. 16.

The Lisbon clay in the Coffeeville area is no better than ordinary garden soil for bleaching oils in the natural state, but it is considerably improved by acid leaching. Samples 2, 4, and 9 are the most activable of the list, but even these fall short of commercial requirements.

T. 8 N., R. 4 E.—The only high-grade activable clays obtained from the Lisbon formation in Clarke County came from sec. 35, T. 8 N., R. 4 E. A deposit covering an area of 2 or 3 acres occurs 4.1 miles east of Whatley on State Highway 44, in the center of the S½NW¼ of sec. 35, on the property of Chris. Jones.

The stratum ranges from 3 to 6 feet in thickness and is covered by a thin mantle of red sandy clay and gray micaceous fine-grained sand. The activable clay bed consists of light-green to greenish-gray, very hard and brittle unctuous material which breaks with conchoidal fracture and is much jointed. The activability of the clay in this deposit varies both laterally and vertically within the bed. It some places the clay of best quality is at the top of the stratum and in others at the base. The varied character of the clay is shown by the bleaching tests of samples from auger holes recorded below.

Part of bed	Raw				Acid-treated			
	G	Y	R	B	G	Y	R	B
Top	0.4	0.5	0.5	0.5	1.0	1.4	1.7	2.8
Middle	.4	.5	.5	.5	1.1	1.7	2.0	2.4
Base	.4	.5	.5	.5	1.0	1.6	2.0	2.1
Top	.3	.4	.4	.4	.9	1.6	1.8	2.0
Middle	.4	.5	.5	.5	.9	1.6	1.9	3.0
Base	.4	.6	.6	.6	1.2	1.7	2.1	3.1
Top	.3	.4	.4	.4	.5	1.0	1.3	2.0
Middle	.3	.4	.5	.5	1.0	1.5	1.8	2.5
Base	.4	.4	.5	.6	.8	1.6	2.0	2.3

Parts of the clay stratum on the Jones farm are well above the minimum requirements for commercially activable clays. However, these high-grade materials are intermingled with less activable clays in such a way as to affect seriously the bleaching properties of the bed as a whole. The amount of available clay is very small, and the bleaching qualities are variable. It is therefore doubtful if this deposit is worthy of commercial attention.

JACKSON FORMATION

Subbentonites are exposed in the Jackson formation east of Whatley and along State Highway 44, in the S½ sec. 20, T. 8 N., R. 4 E., in Clarke County. The beds crop out in the valley of a tributary to Bassett Creek. The hills constituting the valley walls rise to a height of 200 feet or more above the stream, and the clay stratum, which is essentially horizontal, is deeply buried within short distances of the stream course.

Generalized section of bentonitic (?) zone in the SE¼NE¼SW¼ sec. 20. T. 8 N., R. 4 E., Clarke County

	Feet
4. Sands, red and brown, clayey, and sandy clays	20
3. Clay, mottled red and gray, sandy, slightly bentonitic (?)	5
2. Subbentonite, greenish gray and light brown, hard and brittle, unctuous, slightly calcareous; breaks with conchoidal fracture and is much jointed; lower 2 feet is somewhat sandy	5
1. Marl, brownish gray, micaceous, sandy, slightly bentonitic (?).	

The bleaching efficiency of this Jackson subbentonite is shown in the following group of bleach ratings:

Bed	Raw				Acid-treated			
	G	Y	R	B	G	Y	R	B
3	0.4	0.5	0.5	0.5	1.0	1.1	1.1	1.1
	.2	.3	.3	.3	.7	1.1	1.1	1.2
2	.4	.5	.5	.5	1.1	1.8	2.0	2.1
	.3	.4	.4	.4	1.1	1.5	1.8	1.9
	.6	.7	.7	.7	.8	1.1	1.4	1.7
	.3	.4	.4	.4	.9	1.2	1.5	1.8

Although sufficiently improved by acid leaching to be classed as activable clays, the subbentonites of the Jackson formation in this area are not of commercial interest.

CHOCTAW COUNTY DEPOSITS

TALLAHATTA FORMATION

The Tallahatta formation crops out in an irregular-shaped belt across the central part of Choctaw County. Its lithology is varied. It contains incoherent sands, hard quartzite, glauconitic sandstone, porous brittle claystone, and a few thin-bedded bentonitic (?) clays.

Samples of Tallahatta claystone were collected from an exposure located just west of Bogueloosa, in the SW¼ sec. 19. The formation here consists of white to light-gray light and porous claystone which is alternately hard and soft. Unlike the claystone from White Bluff, in Clarke County, this material is very low in natural oil-bleaching efficiency. Bleach ratings of two typical samples, given below, indicate that the Tallahatta at this locality is of no commercial interest as a bleaching clay.

Raw				Acid-treated			
G	Y	R	B	G	Y	R	B
0.5	0.6	0.7	0.7	0.4	0.5	0.6	0.8
.3	.4	.4	.4	.4	.6	.7	.9

A section which is probably stratigraphically higher than that described above occurs along State Highway 29, 7.7 miles north of Gilbertown, in sec. 30, T. 12 N., R. 3 W. This section is described below.

	Ft.	*in.*
7. Sand, greenish gray, slightly clayey	10	0
6. Sand, greenish gray, micaceous, medium- to fine-grained, with quartzitic streaks	1	6
5. Clay, green, hard and brittle, bentonitic, with fine sand laminations		3
4. Sand, indurated, gray, medium-grained		6
3. Clay, green, hard and brittle, bentonitic (?), with coarse sand laminations		5
2. Sand, indurated, gray, medium-grained, with quartzitic streaks	2	0
1. Siltstone, greenish gray, hard and brittle.		

The bentonitic character of beds 3 and 5 is suggested by the way in which these materials are activated by partial acid leaching.

Bed	Raw				Acid-treated			
	G	Y	R	B	G	Y	R	B
3	0.4	0.5	0.6	0.6	1.1	1.7	2.2	2.9
5	.4	.5	.5	.5	1.1	1.7	2.3	3.1

Both of these beds are high enough in activable bleaching efficiency to meet commercial requirements, but the small size of the deposit precludes commercial development. Further investigation may bring to light more extensive occurrences at this apparently bentonitic horizon of the Tallahatta formation.

LISBON FORMATION

For the most part the outcrop of the Lisbon formation is confined to the southern half of Choctaw County. Clays of the activable type are common throughout most of the outcrop, but deposits of commercial grade are very rare. Lisbon clay deposits were investigated in T. 10 N., R. 2 W.; Tps. 9, 10, and 11 N., R. 3 W.; and Tps. 9 and 11 N., R. 4 W. The occurrences of clay in these areas are described below.

T. 10 N., R. 2 W.—A small deposit of clay lies on the top of a small hill in the NE¼NW¼NW¼ sec. 5, T. 10 N., R. 2 W. At this locality an auger hole revealed 3 feet of iron-stained gray unctuous, slightly sandy clay which approximates the requirements for commercial bleaching clays. A sample from the middle of the 3-foot bed gave the following bleach rating:

Raw				Acid-treated			
G	Y	R	B	G	Y	R	B
0.5	0.6	0.6	0.7	1.3	2.0	2.5	2.9

The deposit is too small to be of commercial interest.

T. 9 N., R. 3 W.—Lying between State Highway 29 and the Alabama, Tennessee & Northern Railroad in sec. 20, T. 9 N., R. 3. W, 1.9 miles north of Cullomburg, is a small deposit of activable clay. This material is gray, unctuous, very hard and brittle, and very slightly sandy. The clay stratum in this locality has an average thickness of about 3.5 feet and is covered by an overburden which probably averages about 20 feet. The bleach ratings of clay samples from 4 auger holes scattered over the deposit are given on the following page.

Sample	Raw				Acid-treated			
	G	Y	R	B	G	Y	R	B
1	0.3	0.4	0.4	0.5	1.4	2.0	2.6	2.8
2	.3	.4	.4	.4	1.9	2.5	2.7	2.8
3	.2	.2	.3	.3	1.0	1.7	1.9	2.6
4	.4	.5	.6	.6	1.1	1.7	2.2	2.9

The bleach ratings of samples from this deposit indicate that they are all within the range of commercial interest. The deposit is advantageously located; it parallels the Alabama, Tennessee & Northern Railroad. The brief field examination revealed only a small deposit in this area, but further prospecting might show more extensive bodies of the clay. The deposit is probably too small to support mining operations but is thought to be worthy of commercial attention. This immediate locality warrants detailed investigation.

T. 10 N., R. 3 W.—The following section is exposed in the valley wall of Little Mill Creek on the property of W. H. Pylate, in sec. 5, T. 10 N., R. 3 W.:

	Feet
3. Marl, gray, sandy, fossiliferous	15
2. Clay, thin-bedded, dark gray, waxy, slightly sandy with some interlaminated white fine-grained sand	2
1. Sand, greenish-gray, glauconitic, clayey, medium- to fine-grained.	

As is shown below the bleaching power of the material in bed 2 is too low to be of commercial interest.

Raw				Acid-treated			
G	Y	R	B	G	Y	R	B
0.5	0.5	0.5	0.6	1.0	1.4	1.9	2.0

A 9-foot bed of light-gray micaceous clay near Taylor Mill, on Souwilpa Creek, in the NE¼ sec. 19, is even less efficient for the bleaching of oils than that described above.

T. 11 N., R. 3 W.—A small deposit of activable clay occurs on the farm of Robert Taylor, in the SW¼ sec. 22, T. 11 N., R. 3 W. A generalized section through this deposit is as follows:

	Feet
7. Clay, yellowish to red, sandy	4½
6. Clay, gray, plastic, somewhat sandy	15
5. Clay, gray, hard and brittle, unctuous, bentonitic (?), with numerous soft white calcareous nodules	4
4. Clay, gray, silty, calcareous, bentonitic (?)	4½
3. Clay, interlaminated with gray bentonitic (?) yellowish to brown fine-grained sand; calcareous nodules	4½
2. Like bed 3 but glauconitic	1½
1. Sand, indurated, glauconitic, medium- to fine-grained.	

The activable character of beds 4 and 5 is indicated by the bleach ratings of auger samples given below:

Bed	Raw				Acid-treated			
	G	Y	R	B	G	Y	R	B
5	0.4	0.5	0.5	0.5	1.0	1.6	2.1	2.9
	.1	.2	.2	.2	1.1	1.7	1.8	1.9
	.2	.3	.3	.3	.9	1.2	1.4	1.9
	.1	.4	.4	.4	1.1	1.3	1.7	1.9
	.3	.4	.4	.4	1.1	1.7	2.1	2.8
	.3	.4	.5	.5	.9	1.3	1.7	2.3
4	.2	.3	.3	.3	1.0	1.2	1.3	1.3
	.4	.5	.5	.5	1.1	1.3	1.5	1.6

The samples selected from auger holes bored in the clay deposit on the Robert Taylor farm show this material to be of the activable type, and two samples from the lot are sufficiently high in bleaching power to be classed as commercial. The average run of the samples, however, is below the commercial grade of bleaching clay, and the deposit is not thought to be of commercial interest.

T. 9 N., R. 4 W.—A deposit of activable clay 1.9 miles west of Bolinger, on the property of David Swann, covers an area of 12 to 15 acres in secs. 2 and 3, T. 9 N., R. 4 W., in Choctaw County. The bed consists of gray unctuous hard and brittle noncalcareous clay, which has an average thickness of about 5 feet. Over half of the deposit is covered by a very thick overburden, which has a maximum thickness of about 50 feet.

A generalized section through the deposit is as follows.

	Feet
5. Clay, orange and red, medium-grained, sandy, with interbedded sand and occasional rounded quartz pebbles	10
4. Clay, iron-stained, gray, highly sandy, plastic	5
3. Subbentonite, gray, hard and brittle, unctuous	5
2. Like bed 3, but glauconitic	½
1. Clay, bluish gray, fossiliferous, micaceous, brittle, silty.	

Three samples obtained from auger holes in bed 3 show this stratum to be distinctly activable. Sample 1 in the table below is sufficiently activable to approach commercial requirements. This was taken from an auger hole just west of the Swann dwelling. It is doubtful if there is enough of the better-grade activable clay in this deposit to make it of interest for mining purposes. The bleach ratings are as follows:

Sample no.	Raw				Acid-treated			
	G	Y	R	B	G	Y	R	B
1	0.4	0.5	0.5	0.5	1.1	1.8	2.2	2.6
2	.2	.3	.3	.3	1.3	1.8	1.9	1.9
3	.3	.4	.4	.4	1.0	1.4	1.6	1.8

T. 11 N., R. 4 W.—The northernmost occurrence of Lisbon activable clay examined in Choctaw County was an exposure 4 miles northwest of Toxey, in the NE¼ sec. 3, T. 11 N., R. 4 W. The stratum consists of gray and greenish-gray hard and brittle unctuous, rather fine sandy clay. The average thickness of the bed is about 5 feet. The following bleach rating shows this material to be somewhat activable but not sufficiently so to be of commercial interest:

Raw				Acid-treated			
G	Y	R	B	G	Y	R	B
0.4	0.5	0.5	0.5	1.4	2.0	2.1	2.1

JACKSON FORMATION

The Jackson formation curves around the northwest end of the Hatchetigbee anticline in the southern part of Choctaw County. In this area the formation consists of calcareous clays, yellowish and gray marl, yellow calcareous and clayey sands, and greenish-gray calcareous subbentonites. The subbentonitic phase of the Jackson formation in Choctaw County is activable, but no beds were found sufficiently high in bleaching power to be of commercial interest. This phase of the Jackson was examined in T. 9 N., R. 3 W.; T. 9 N., R. 5 W.; and T. 10 N., R. 3 W.

T. 9 N., R. 3 W.—The following section was penetrated in an auger hole in the SW¼NW¼ sec. 33, T. 9 N., R. 3 W.:

	Feet
6. Subbentonite, gray, unctuous, highly calcareous, with numerous white calcareous nodules	4
5. Subbentonite, light tan to greenish-gray, unctuous, hard and brittle, slightly calcareous	7
4. Like bed 5, with numerous calcareous nodules	2
3. Same as bed 5	2
2. Subbentonite, greenish gray, hard and brittle, calcareous, glauconitic	2
1. Greensand, fine.	

A sample from the middle of bed 5 gave the following bleach rating:

Raw				Acid-treated			
G	Y	R	B	G	Y	R	B
0.3	0.5	0.5	0.5	0.9	1.4	1.6	1.8

This deposit lies within a few hundred yards of the Alabama, Tennessee & Northern Railroad and would be readily accessible, but the quality of the clay is too poor for commercial development.

A rather extensive deposit of clay very similar in appearance and bleaching properties to that described above occurs on the property of W. H. Stanley, half a mile southwest of Cullomburg. A sample selected from the middle of a 15-foot exposure on this property showed this material to be low grade.

Raw				Acid-treated			
G	Y	R	B	G	Y	R	B
0.4	0.5	0.5	0.5	0.9	1.3	1.5	1.9

T. 9 N., R. 5 W.—A very thick clay bed was revealed in a bore hole 1.1 miles south of Isney on the Bolinger road. The section is as follows:

	Feet
3. Clay, gray, plastic, slightly sandy, calcareous	3
2. Like bed 3, but less plastic and calcareous	2
1. Subbentonite, dark bluish gray, hard and brittle, unctuous, foraminiferal	20+

Bleach ratings of samples from bed 1 are as follows:

Distance from top (feet)	Raw				Acid-treated			
	G	Y	R	B	G	Y	R	B
3	0.5	0.6	0.7	0.7	0.8	1.0	1.2	1.8
11	.4	.5	.6	.6	.8	1.1	1.3	1.6
20	.3	.4	.4	.4	1.0	1.2	1.3	1.5

These bleach ratings indicate that the Jackson subbentonite of the Isney area is of too low grade to be of commercial interest.

T. 10 N., R. 3 W.—Bentonitic clay in the Jackson formation is exposed 1 mile south of Gilbertown on State Highway 29. The following section in the center of sec. 6, T. 10 N., R. 3 W., was penetrated by the auger:

	Feet
5. Subbentonite, greenish gray, calcareous, unctuous, slightly sandy; contains occasional white lime nodules	12
4. Like bed 5, with numerous limy nodules and interlaminated white fine-grained sand	2
3. Subbentonite, greenish gray, very hard and brittle, unctuous, slightly calcareous	6
2. Like bed 3 but glauconitic	2
1. Greensand, fine-grained.	

The activable character of the clay described above is shown by the following bleach ratings:

Sample	Raw				Acid-treated			
	G	Y	R	B	G	Y	R	B
Bed 5:								
5 feet from top	0.3	0.4	0.4	0.4	0.8	1.4	1.6	1.8
10 feet from top	.2	.3	.4	.4	1.2	1.5	1.5	1.5
Bed 3:								
3 feet from top	.3	.4	.4	.4	1.2	1.7	1.8	1.8
Bed 2:								
1 foot from top	.4	.5	.5	.5	1.0	1.2	1.3	1.3

This deposit is not of commercial interest.

A 15-foot bed of greenish-gray, slightly sandy unctuous subbentonite that is highly calcareous near the top is exposed on the property of Frank Stewart in the NE¼SW¼ sec. 2, T. 10 N., R. 3 W. As is shown in the following bleach rating, this clay is too poor to be of commercial interest:

Raw				Acid-treated			
G	Y	R	B	G	Y	R	B
0.4	0.5	0.5	0.5	1.1	1.4	1.6	1.8

SUMMARY AND CONCLUSIONS

Material of bleaching-clay type occurs in the Tallahatta, Lisbon, and Jackson formations in Clarke and Choctaw Counties, Ala.

A deposit of fuller's earth that appears to be worthy of commercial attention occurs in the Tallahatta formation at White Bluff, on the Tombigbee River near Cunningham, in Clarke County. Very thin beds of high-grade activable clay occur in the Tallahatta north of Gilbertown, in Choctaw County. These deposits are too small for commercial exploitation.

Activable clays are common in the Lisbon formation in Clarke and Choctaw Counties. A few samples of this material might qualify as commercial clays if not intermingled with inferior clays in such manner as to make mining impracticable. A deposit 1.9 miles north of Cullomburg, in Choctaw County, approaches commercial grade but is very small.

Many of the deposits of Jackson clay in these two counties are rendered somewhat active by partial acid leaching, but no deposits of commercial importance were found in this formation.

SUPPLEMENTARY INVESTIGATIONS OF ALABAMA BLEACHING CLAYS

By A. C. Munyan

AREAS EXAMINED AND RESULTS

Outcrops of clay beds in Mesozoic and Cenozoic rocks were studied and sampled in many places. The area covered included the central, eastern, and southern portions of the Coastal Plain region of Alabama. On the accompanying map (pl. 6) all localities visited are shown; and in the tables the locations of the samples are described in more detail.

The tables show that most of the samples were of little or no value as bleaching clays. Not only is the bleaching power of most samples low, but the beds are thin or contain too great an admixture of sand. However, a deposit of bentonite northeast of Montgomery, in Montgomery County, proved to be an excellent bleaching clay, and this deposit is discussed in some detail. It is possible that exposures of high-grade material were overlooked during this survey and that a more detailed examination might discover some excellent bleaching clays.

EXPLANATION OF TABLES

All samples and their locations are listed in the accompanying tables, regardless of the degree of activability indicated by the bleaching tests. The data on thickness of bed and lithologic character of the clays are also included in these tables. The samples and locations are grouped according to formations from which they came, in stratigraphic order, beginning with the oldest formation examined, which was the Upper Cretaceous Eutaw formation. As most of the samples tabulated appear to be of no commercial interest, no additional discussion of them appears necessary, and only the more promising clay deposit near Montgomery is considered in more detail.

BENTONITE DEPOSIT NEAR MONTGOMERY

The deposit of bentonite near Montgomery is the only clay examined that appears from bleaching tests to be of possible commercial interest. These tests indicate a very efficient bleaching clay, and though the deposit appears to be small, additional prospecting at this horizon may disclose more extensive deposits in the region. The bentonite occurs in the upper part of the Eutaw formation, which is composed chiefly of fine- to medium-grained glauconitic sand and is about 400 feet thick.

The locality is indicated as station 7 on the general map (pl. 6), and details at this locality are presented in the sketch map (fig. 27). At station 7A, at the edge of a steep-walled gully, on the property of Bliss Edgar, in the NW¼ sec. 8, T. 16 N., R. 18 E., the following section is exposed:

	Feet
5. Sand and soil, dark red, coarse-grained, somewhat massive	10
4. Clay, cream-colored at top, pink at base, very waxy, granular texture	3
3. Sand, soft, red, medium-grained, cross-bedded	20
2. Clay, dark tan, waxy, sandy, mica flakes	1½
1. Sand, light gray and tan; highly cross-bedded, typical Eutaw	60

The sample from the upper clay bed gave an excellent bleaching test, equaling in quality the best activable bentonites known. The petrographic microscope indicates a pyroclastic texture with a great many relict shards, thus definitely establishing the volcanic origin of the bed. The sample from the bed 20 feet lower in the section is not of so high a grade but nevertheless is an activable clay well within the commercial range.

Several other points were sampled, including stations 7B, 7C, 7D, and 7E. In each of these the beds are so thin (6 to 8 inches) that they

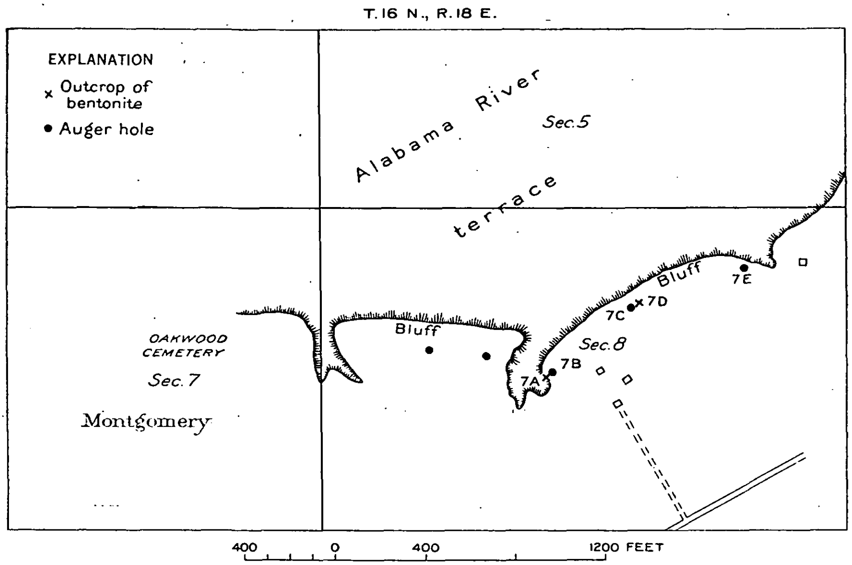

FIG. 27.—Sketch map of bentonite locality near Montgomery, Ala. By A. C. Munyan.

are of no economic value. On the sketch map two auger holes are shown west of station 7A. The bentonite bed was not found in these holes, either having been removed by erosion soon after deposition or never having been deposited there. If, however, a sufficient quantity of this material could be located, it would greatly merit the attention of commercial operators.

RESULTS OF PROSPECTING AND TESTING

The details of the test borings and of the samples tested are given in the following table. The symbols used are explained on pages 14 and 15.

Bleach ratings of clay samples from Upper Cretaceous formations of Alabama

Eutaw formation

Station No.	Location	Description of bed: Character	Description of bed: Thickness (Ft. in.)	Position of sample in the bed	Oil bleach, Raw: G	Raw: Y	Raw: R	Raw: B	Acid-treated: G	Acid-treated: Y	Acid-treated: R	Acid-treated: B	Acid-soluble: Fe	Al	Ca	Off (per-cent)
1	Hale County; 2.3 miles southeast of Havana, 1 mile N. 40° E. of the road in a deep gully.	Cream gray, massive, waxy, and greasy.	6	Composite	0.7	0.8	0.8	0.8	1.1	1.2	1.3	1.4	4	5	1	15
2	Hale County; 3.8 miles north of Greensboro Hotel on Havana road, northward slope to Big Creek.	Buff, mottled brown, laminated, waxy, sandy.	(?) (Slumped)		.3	.4	.4	.4	1.1	1.2	1.3	1.3	5	4	1	30
3	Hale County; 1.1 miles north of Greensboro Hotel on Havana road.	Gray, mottled red, waxy, gritty, siliceous nodules.	7 0	Composite	.2	.3	.3	.3	1.1	1.2	1.2	1.2	5	4	1	20
5	Hale County; 2 miles south of Greensboro Hotel on Uniontown road.	Greenish gray, mottled red and yellow, waxy, sandy, glauconitic.	5 0	do	.8	.9	.9	1.0	1.1	1.4	1.5	1.5	3	2	5	20
6	Dallas County; near center of sec. 26, T. 18 N., R. 11 E., road cut of Northeast-Southwest road on south face of hill.	Dark gray, laminated, waxy, sandy, small sand laminae at base.	4 0	Basal 1 foot	.3	.4	.4	.4	1.6	1.8	1.9	2.0	6	4	Tr	25
				Top 1 foot	.2	.3	.3	.3	1.1	1.4	1.5	1.5	5	4	1	20
7A	Montgomery County; NW¼ sec. 8, T. 16 N., R. 18 E., second gully northeast of Oakwood Cemetery, property of Bliss Edgar.	Cream at top, pink at base, massive, waxy, greasy, granular.	3 0	Composite	.2	.3	.3	.3	2.0	2.7	2.8	2.8	6	4	Tr	25
------	20 feet below other sample at this location.	Dark tan, laminated, waxy, sandy, some mica.	1 6	do	.5	.6	.6	.6	2.0	2.6	2.8	2.9	6	4	Tr	20
7B	Auger hole 10 feet northeast of station 7A; same bed as upper one at station 7A.	Cream-colored, massive, waxy, granular.	6	do	.2	.3	.3	.3	1.2	1.9	2.8	3.8	5	5	0	30
------	do	do	6	do	.1	.2	.2	.2	1.1	1.7	2.5	3.5	5	5	Tr	25
------	do	do	7	do	.2	.3	.3	.3	1.9	2.9	3.0	3.0	4	5	Tr	25
------	do	Pink, massive, waxy and greasy.	7	do	.3	.4	.4	.4	2.0	3.0	3.7	3.9	4	5	Tr	30
------	do	Cream-colored, massive, very waxy and greasy.	3	do	.3	.4	.4	.4	1.9	2.8	2.9	2.9	4.	5	Tr	25
7C	Auger hole 500 feet N. 50° E. of station 7A; same bed as upper one at station 7A.	Grayish cream, massive, waxy and greasy.	7	do	.5	.6	.6	.6	1.9	3.0	3.3	3.7	6	4	Tr	30
7D	Outcrop 15 feet east of station 7C; same bed as upper one at station 7A.	Cream-colored, massive, waxy, greasy.	8	do	.2	.3	.3	.3	1.1	1.9	2.7	3.4	6	4	0	30
7E	Auger hole 1,000 *feet* N. 60° E. of station 7A; same bed as lower one at station 7A.	Gray, laminated, somewhat waxy, very sandy.	1 0	do	.6	.7	.7	.7	1.1	1.7	1.9	2.0	5	4	1	25
8	Montgomery County; railroad cut facing Alabama *River, 0.5 mile west of* Montgomery Union Station.	Gray, laminated, a little waxy, gritty, very lenticular.	5	do	.3	.4	.4	.6	1.4	1.4	1.4	1.4	5	4	1	25
9	Montgomery County; near center of SW¼ sec. 23, T. 16 N., R. 17 E., in road ditch.	Gray, mottled red, earthy, sandy.	6	do	.5	.6	.6	.6	1.4	1.5	1.6	1.6	5	4	1	25

10	Montgomery County; U. S. Highway 80, 11 miles east of Court Square, Montgomery.	Gray, mottled red, laminated, waxy, sandy.	5	0	Basal 1 foot	.4	.6	.7	.7	1.1	1.6	1.9	2.1	6	4	0	25
11	Montgomery County; U. S. Highway 80, 4 miles east of Mount Meigs.	Greenish gray, mottled brown, waxy, sandy.	1	0	Composite	.5	.6	.6	.6	1.2	1.7	1.8	1.9	5	4	1	25
12	Macon County; U. S. Highway 29, 5.4 miles south of Tuskegee Square.	Greenish gray, mottled red, waxy, sandy.	4	0	do	.3	.4	.4	.4	1.6	2.2	2.4	2.5	5	4	1	30
13	Russell County; Alabama Highway 241, 3.7 miles south of lower bridge across Chattahoochee River at Columbus, Ga.	Greenish gray, waxy, sandy	8	8	Top 1 foot	.3	.4	.4	.4	1.2	1.3	1.3	1.3	5	5	0	20
					3 feet below top	.2	.3	.3	.3	1.2	1.2	1.2	1.2	5	5	0	20
					5 feet below top	.2	.3	.3	.3	1.3	1.3	1.3	1.3	5	5	0	25
					6.7 feet below top	.3	.4	.4	.4	1.1	1.1	1.1	1.1	6	4	0	30
					8.8 feet below top	.2	.3	.3	.4	1.2	1.2	1.2	1.2	5	5	0	20
14	Auger hole; Alabama Highway 241, 0.3 mile south of station 13.	Gray, mottled red, waxy; sandy.		6	Top 6 inches	.5	.6	.6	.7	.8	1.3	1.6	1.7	6	4	0	30
		Greenish gray, waxy, sandy	13	0	1 foot below top	.5	.6	.7	.8	1.0	1.4	1.6	1.6	5	5	0	20
					3.5 feet below top	.4	.5	.5	.5	.7	.7	.7	.7	5	5	0	20
					5.8 feet below top	.3	.4	.4	.5	1.2	1.4	1.5	1.5	5	5	0	20
					8.1 feet below top	.5	.6	.6	.6	1.0	1.5	1.7	1.9	5	5	0	25
					11.5 feet bleow top	.4	.5	.5	.5	.7	.7	.7	.7	6	4	0	25
15	Russell County; Alabama Highway 241, 1.1 miles south of station 14.	Red, mottled brown, waxy, gritty.	2	6	2.2 feet below top	.6	.7	.7	.7	1.1	1.5	1.6	1.8	7	3	0	35
		Gray, waxy, sandy	5	11	3.3 feet below top	.1	.2	.2	.2	.8	1.0	1.1	1.1	5	5	tr.	25
					5.7 feet below top	.2	.3	.3	.3	1.0	1.1	1.1	1.1	5	5	0	20
					8.4 feet below top	.2	.3	.3	.3	1.1	1.2	1.2	1.2	6	4	tr.	25
16	Russell County, Alabama Highway 241, 0.3 mile south of station 15.	Gray, waxy, very sandy at top but decreasing toward base.	8	10	1 foot below top	.6	.7	.7	.8	1.1	1.7	1.9	2.0	5	5	0	25
					3 feet below top	.4	.5	.6	.7	.9	1.2	1.3	1.5	5	5	0	25
					4.9 feet below top	.5	.6	.6	.7	.9	1.1	1.2	1.2	5	5	tr.	20
					7.4 feet below top	.5	.6	.6	.6	1.1	1.6	1.7	1.7	5	5	tr.	20
					8.8 feet below top	.5	.6	.6	.7	1.1	1.4	1.5	1.5	6	4	tr.	25
17	Russell County; Alabama Highway 241, 1.3 miles south of station 16.	Dark gray, laminated, waxy, sandy, some mica.	10	0	Basal 1 foot	.6	.7	.7	.8	1.0	1.2	1.3	1.5	5	5	0	20
					Selma chalk												
19	Hale County; Uniontown-Greensboro road, 1.5 miles north of railroad station in Newbern.	Medium gray, laminated, waxy, hard.	0	½	Composite	0.2	0.3	0.3	0.3	1.1	1.6	1.8	2.2	5	4	1	30
20	Hale County; Uniontown-Greensboro road, 9.1 miles north of U. S. Highway 80 in Uniontown.	Greenish tan and gray, laminated, waxy, sandy.	3	0	do	.5	.6	.6	.6	.9	1.0	1.1	1.1	3	2	5	20
21A	Dallas County; U. S. Highway 80, 9.3 miles southeast of Alabama River bridge at Selma, north side of road.	Yellowish olive; laminated, waxy, sandy.	2	0	do	.7	.9	1.0	1.1	2.0	2.3	2.4	2.5	6	3	1	25
21B	Auger hole 10 feet north of station 21A	Greenish gray, waxy, gritty	2	4	Top 6 inches	.4	.5	.5	.5	1.1	1.7	1.8	1.9	5	4	1	25
					2 feet below top	.6	.8	.9	.9	.8	1.0	1.2	1.4	1	tr.	9	60
21C	Auger hole 150 feet S. 23° E. of station 21A.	Gray with green tinge, waxy, gritty.	3		Top 6 inches	.6	.7	.8	.8	.7	1.1	1.3	1.9	5	4	1	30
					2 feet below top	.5	.6	.6	.7	.7	.9	1.1	1.3	5	4	1	30
					3 feet below top	.3	.4	.4	.4	.8	1.2	1.4	1.5	1	1	8	60
21D	Auger hole 650 feet N. 15° W. of station 21A, then 300 feet north.	Gray; mottled brown, waxy, gritty, some manganese.	1	0	Composite	.6	.7	.7	.7	1.1	1.4	1.8	2.2	5	2	3	35

Bleach ratings of clay samples from Tertiary formations of Alabama

Midway group (Clayton formation)

Station No.	Location	Description of bed		Position of sample in the bed	Oil bleach								Acid-soluble (percent)			
		character	Thickness		Raw				Acid-treated				Fe	Al	Ca	Off
					G	Y	R	B	G	Y	R	B				
			Ft. in.													
22	Butler County; U. S. Highway 31, 5.2 miles north of Louisville & Nashville Railroad under pass in Greenville, near small cemetery on west side of road.	Grayish tan mottled red, laminated, waxy, sandy.	5 0	Base	0.7	0.8	0.9	0.9	0.6	0.7	0.8	1.0	6	4	0	30
23A	Barbour County; 1 mile east of courthouse in Clayton on Eufaula road, 600 feet north along Central of Georgia Railroad to cut.	Light gray when fresh, weathering chalk white, laminated, waxy, free from gritty material.	8 0	Middle 1 foot	.8	.9	1.0	1.2	1.1	1.3	1.5	1.8	6	3	1	20
				Base	1.2	1.4	1.5	1.6	.7	1.0	1.2	1.5				
23B	Auger hole 50 feet east of station 23A	Light gray, waxy, not sandy, very hard.	6 6+	Top 6 inches	.2	.3	.3	.3	1.1	1.2	1.2	1.2	5	4	1	30
				2.9 feet below top	.7	.9	1.0	1.2	.9	1.4	1.9	2.2	4	5	1	20
				5.5 feet below top	.7	.9	1.0	1.2	.6	.8	1.1	1.3	5	4	1	25

Wilcox group

[24 from Nanafalia formation; 25 and 26 from Tuscahoma sand; 27 from Hatchetigbee formation]

Station No.	Location	character	Thickness	Position of sample in the bed	G	Y	R	B	G	Y	R	B	Fe	Al	Ca	Off
24	Butler County; U. S. Highway 31, 9.8 miles south of Louisville & Nashville Railroad underpass in Greenville.	Greenish gray, irregularly bedded, somewhat waxy, sandy.	3 0	Composite	0.6	0.7	0.7	0.7	1.0	1.4	1.7	2.2	5	5	0	30
25	Butler County; U. S. Highway 31, 12.4 miles south of Louisville & Nashville Railroad underpass in Greenville.	Gray, irregular bedding, a little waxy, sandy.	4 0	do	.6	.7	.7	.7	.7	.9	1.1	1.3	5	5	0	25
26	Crenshaw County; Luverne-Andalusia road, 4.25 miles south of courthouse in Luverne.	Light olive, laminated, waxy, a little gritty.	3 0	do	.2	.3	.3	.3	1.1	1.6	1.7	1.7	5	4	1	25
27	Butler County; U. S. Highway 31, 2.9 miles north of McKenzie railroad station.	Gray when fresh, white when weathered, bedded, gritty, hackly fracture, fossiliferous.	15 0	Top 1 foot	.6	.7	.8	.8	.6	.7	.8	1.0	6	4	0	20
				6 feet below top	.6	.7	.7	.7	.6	.7	.8	1.0	7	3	0	15

Claiborne group (Tallahatta formation)															
28	Covington County; Alabama Highway 55, 5.8 miles southeast of McKenzie railroad station, slope down to Pigeon Creek.	White, bedded, not gritty, blocky fracture.	6	0	Composite	0.8	0.9	1.0	1.0	0.6	0.7	0.8	0.8	6	4	0	20
Vicksburg group															
29	Coffee County; Alabama Highway 27, 9.6 miles south of Atlantic Coast Line underpass at Enterprise.	Gray, mottled brown, massive, waxy, a little gritty.	2	0	Composite	0.6	0.7	0.7	0.8	1.0	1.2	1.3	1.5	6	4	0	30
30	Geneva County; Alabama Highway 12, along north boundary of sec. 33, T. 2 N., R. 24 E., west side of Hurricane Creek.	Gray, mottled brown, somewhat laminated, sandy.	3	0	do	.6	.7	.8	.9	.8	.9	1.0	1.2	7	3	0	35
31	Houston County; Alabama Highway 52, 2 miles west of Dothan post office.	Gray, mottled purple, laminated, sandy.	2	0	do	.6	.7	.7	.8	.9	1.2	1.3	1.5	6	4	0	25
32	Houston County; U. S. Highway 231, 5.6 miles south of Dothan post office, north side of Limestone Creek.	Gray, mottled red, laminated but irregularly, waxy, sandy.	3	0	do	.9	1.0	1.1	1.1	1.1	1.5	1.7	1.9	7	2	1	20
33	Houston County; U. S. Highway 231, Dothan-Cottonwood Road, 6.5 miles southwest of Atlanta & St. Andrews Bay Railroad crossing at southeast edge of Dothan.	Tan, mottled brown, hackly, waxy, sandy.	3	0	do	.6	.7	.7	.8	1.0	1.1	1.2	1.3	5	5	0	25
34	Houston County; Dothan-Cottonwood Road, 1.8 miles southeast of station 33.	Gray, mottled red, waxy, sandy.	10	0	do	.7	.8	.8	.9	1.1	1.2	1.3	1.4	4	6	0	20
35	Houston County; U. S. Highway 84, 8.6 miles east of Dothan post office, road ditch on south side.	Brick red, streaked white, somewhat waxy, sandy.	8	0	do	.8	.9	.9	.9	.8	1.0	1.1	1.2	7	3	----	20
36	Houston County; sec. 32, T. 3 N., R. 29 E., east edge of section on road descending to Cedar Creek.	Brown, concentric layers, somewhat waxy, sandy, much chert.	3	0	do	.7	.8	.9	1.0	.7	1.0	1.1	1.3	7	3	0	25
37	Houston County; south central portion sec. 4, T. 3 N., R. 29 E.; on county road.	Brown, mottled red, waxy, sandy.	3	0	do	.7	.8	.8	.9	.8	1.0	1.1	1.4	6	4	0	25
38	Houston County; SE¼ sec. 4, T. 3 N., R. 29 E., on north-south county road.	Brown, mottled red and gray, waxy, sandy.	5	0	do	.7	.8	.9	1.1	.7	.9	1.1	1.5	3	7	0	30

Chapter 8.—A PRELIMINARY INVESTIGATION OF THE BLEACHING CLAYS OF MISSISSIPPI

By Harry X. Bay

ABSTRACT [51]

Bleaching clays in Mississippi include fuller's earth and bentonites (?) or activable clays. The bentonites (?) afford greatest promise of commercial development, and attention was therefore centered upon them. The bentonites (?) are found in successively younger formations from the northeastern part of the State southwestward, beginning with those of the Eutaw formation, of Cretaceous age, in Itawamba, Monroe, and Prentiss Counties. The beds near Aberdeen, in Monroe County, are in the Tombigbee sand member of this formation, and those being worked by the Williams Brothers and Wroten Co. south of Booneville are in the Coffee sand member.

The Porters Creek formation, which is somewhat bentonitic, is a member of the Midway group, of Eocene age. It crops out in Chickasaw, Kemper, Noxubee, Oktibbeha, Pontotoc, Tippah, Union, and Webster Counties and crosses northward into Tennessee and eastward into Alabama. Its characteristics are described in the chapters on Tennessee and Alabama. Although low-grade bleaching clay is being produced from this formation in Illinois, in Mississippi it affords no promise of successful commercial development.

The Yazoo clay member of the Jackson formation (Eocene) contains bentonite (?) near Jackson, in Hinds County; near Lake, in Scott County; and at Satartia, in Yazoo County, where it is thin and of small extent. In northern Wayne County the bentonite (?) is sandy and limy and is present in thick beds but is of inferior quality and of no commercial interest.

By far the most efficient activable bleaching clay found in Mississippi is in the Vicksburg group, of Oligocene age, in the central and eastern parts of the State. Extensive deposits of bentonite (?) extending in a narrow belt westward from Lemon and Lorena, in Smith County, offer distinct commercial possibilities. High-grade bentonite (?) is also present near Heidelberg, in southeastern Jasper County, but the deposit is too thin to support any considerable exploitation. In central and eastern Wayne County the Vicksburg bentonitic beds are extensive and thick but too sandy to have much bleaching power and hence are of little commercial value.

Rather extensive deposits of naturally active clay (fuller's earth) have been reported from the Catahoula sandstone (Miocene) of Smith County. These were not studied, but a sample from a locality near Mize, Smith County, was tested in the Geological Survey laboratory. It was soft and powdery and did not lend itself to granulation, a necessary requirement for fuller's earths that are to be used for bleaching oil. Its bleaching power was very low.

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[51] This paper has been published in full under the above title as Mississippi Geol. Survey Bull. 29, 1935.

Chapter 9.—THE BLEACHING CLAYS OF GEORGIA

By Harry X. Bay and Arthur C. Munyan

INTRODUCTION

By G. R. Mansfield

Two separate allocations of funds to the Geological Survey from the Public Works Administration made possible the study of Georgia bleaching clays. Mr. Bay with the first field party worked during September and October 1934. The second field party, in April and May 1935, was in charge of Mr. Munyan. A brief summary of the results of this investigation has been published.[52]

Purpose and methods of investigation.—The purpose of this study was to obtain information concerning the bleaching-clay industry within the State, to attempt to extend knowledge of productive beds, to examine other formations for possible new deposits, to evaluate roughly the size and thickness of any such new beds, and to lay the foundations for possible systematic future development.

The investigation consisted chiefly of a reconnaissance of several geologic formations considered likely to contain suitable deposits of bleaching clay. The methods employed were those described on page 3 and involved both outcrop study and boring. For boring two men were required.

Acknowledgments.—Thanks are due to the Attapulgus Clay Co., Attapulgus, Ga.; the General Reduction Co., Macon, Ga.; the Mineral Products Co., Ochlochnee, Ga.; and the Hall Clay Co., Irwinton, Ga., for information concerning their operations. The writers are also indebted to the members of the Georgia Geological Survey for their aid, as well as to Messrs. John Purdom, of the Atlantic Coast Line Railroad; Rex Henry and J. M. Dobbins, of Cassandra, Ga.; E. F. Dorsey, of Dry Branch, Ga.; and J. M. Hughes, of Cairo, Ga.

All samples collected were tested by P. G. Nutting, of the Geological Survey. L. W. Stephenson and C. W. Cooke, of the Survey, were of particular aid in solving many field problems.

A discussion of the origin and nature of bleaching clays and of the methods of testing them is given in the introductory chapter (pp. 13–15).

[52] Bay, H. X., and Munyan, A. C., The bleaching clays of Georgia: Georgia Dept. Forestry and Geol. Development Inf. Circ. 6, 1935.

THE BLEACHING CLAYS OF GEORGIA

By Harry X. Bay

OCCURRENCE

Bleaching clays occur within five distinct formations and areas in Georgia. Ranging from oldest to youngest these are (1) the Ordovician bentonite, so called, in the Chickamauga limestone of Chattooga, Dade, and Walker Counties; (2) the fuller's earth in the Eocene Midway formation of Stewart County; (3) the fuller's earth in the Twiggs clay member of the Eocene Barnwell formation of Crawford, Houston, Jones, Twiggs, Washington and Wilkinson Counties, (4) the bentonitic (?) clay in the Oligocene Flint River formation of Crisp, Dooly, Macon and Sumter Counties, and (5) the fuller's earth in the Miocene Hawthorn formation of Decatur, Grady, and Thomas Counties.

PRODUCTIVE AND POSSIBLY PRODUCTIVE DEPOSITS

Georgia produces more fuller's earth than any other State. The Attapulgus Clay Co., said to be the largest fuller's earth company in the world, is producing naturally active clay from the Hawthorn formation in Decatur County. The General Reduction Co., has been operating in Twiggs County for many years. Its product comes from the Twiggs clay member of the Barnwell formation. The Hall Clay Co. is operating a small fuller's earth quarry near Irwinton, in Wilkinson County.

Several unsuccessful attempts have been made to market naturally active clay from the Midway formation near Lumpkin, in Stewart County.

At the present time no activable clay is produced within the State. Clays of the activable type occur in the Chickamauga limestone in northwestern Georgia, but these are not sufficiently activable to be of commercial importance. It is thought that the bentonitic (?) clays of the Flint River formation in central and southern Georgia may provide sufficient high-grade activable clays to support commercial production. Much of the so-called fuller's earth of the Twiggs clay member of the Barnwell formation is activable, but in only a few localities is it sufficiently so to justify acid treatment on a commercial scale. Further prospecting at this horizon may reveal other commercial deposits of activable clay.

ORDOVICIAN CLAYS

CHICKAMAUGA LIMESTONE

According to Smith,[53]

> The Chickamauga limestone in Georgia includes all the rocks of Ordovician age lying above the Knox dolomite and below the Red Mountain formation, with the exception of the Rockmart slate * * * The Chickamauga formation is exposed in long, narrow areas where the rocks are steeply dipping, and broad valleys where exposed on the crests of gentle anticlines * * * Bentonite * * *

[53] Smith, R. W., Shales and brick clays of Georgia: Georgia Geol. Survey Bull. 45, p. 59, 1931.

occurs in a bed 1 to 20 feet in thickness in limestone of Black River (Lowville) or basal Trenton age in the valleys of Lookout and West Chickamauga Creeks.

The bentonite horizon of the Chickamauga limestone is exposed in parts of Chattooga, Dade, and Walker Counties, where it crops out in thin steeply dipping beds. The bentonite occurs in two zones separated by several feet of bluish-gray limestone. The upper zone, which crops out in the vicinity of High Point and Coopers Heights, in Walker County, consists of mottled light-brown or pale-green soft, mealy, highly micaceous bentonite which locally contains small white limy concretions and a small admixture of fine sand. The lower zone, which is well developed south of Cassandra, in Walker County, and near Harrisburg, in Chattooga County, reaches a maximum thickness of about 8 feet and is composed of greenish-gray to pale-green soft and mealy to hard and brittle, unctuous, very slightly arenaceous bentonite.

Both the upper and the lower bentonite beds lie between thick layers of limestone and are inclined at angles as great as 45°. The maximum thickness is thought not to exceed 8 feet. Such a thickness of clay occurring between thick limestone beds and dipping at high angles would offer serious difficulty in mining. These factors coupled with the low activable bleaching efficiency of the bentonite preclude any large-scale commercial activity in this field.

CHATTOOGA COUNTY

Harrisburg station area.—A bed of iron-stained greenish-gray unctuous, mealy to hard and brittle, very slightly sandy bentonite crops out on the east flank of Pigeon Mountain on the property of J. J. Gilreath, lot 55, 13th district, 4th section, in Chattooga County, just south of Harrisburg station. (See pl. 7.) The bed extends southward and was noted on the adjoining property of John Stoker. It is associated with limestone beds, is about 8 feet thick and dips 35° NW. Samples were obtained from auger holes and showed the following bleach ratings:

Sample	Raw				Acid-treated			
	G	Y	R	B	G	Y	R	B
Gilreath:								
No. 1:								
Top	0.6	0.7	0.8	0.8	1.1	1.5	1.6	1.9
Middle	.4	.5	.5	.5	1.1	1.5	1.6	1.9
Base	.5	.6	.7	.7	1.2	1.5	1.6	1.8
No. 2:								
Top	.5	.6	.6	.6	.8	1.1	1.4	1.6
Middle	.5	.6	.7	.7	.8	1.1	1.4	1.8
Base	.5	.6	.6	.6	1.1	1.3	1.6	1.9
Stoker:								
Top	.7	.8	.9	1.0	1.1	1.5	1.7	1.9
Middle	.6	.7	.8	.8	1.2	1.5	1.7	2.0
Base	.6	.7	.7	.7	.9	1.3	1.6	1.9

The bleach ratings indicate that this material is a bleaching clay of the activable type, but it is not sufficiently activable to be of commercial grade. (See p. 15.)

DADE COUNTY

Bentonitic clay occurs near Trenton and Rising Fawn, in Dade County, on the west flank of Lookout Mountain. The Trenton occurrence is assigned to the upper bentonitic horizon, and that near Rising Fawn to the lower bed. (See pl. 7.)

Trenton area.—Bentonitic clay is exposed in a road cut adjoining the property of Eph. Rogers, three-quarters of a mile west of Trenton on the road to White Oak Gap. The bentonitic stratum here is about 6 feet thick. It lies between beds of Chickamauga limestone which dip 32° NW. The clay is soft and buff-colored and is speckled with golden-yellow mica. The lower part of the bed is calcareous. The entire thickness is somewhat sandy.

The bleaching properties of this material are shown below.

Part of bed	Raw				Acid-treated			
	G	Y	R	B	G	Y	R	B
Top	0.5	0.6	0.6	0.6	0.6	1.0	1.3	1.3
2 feet below top	.5	.6	.6	.6	.7	1.0	1.3	1.5
4 feet below top	.5	.6	.6	.6	.6	1.0	2.0	2.0
Base	.4	.5	.5	.5	.7	1.0	1.2	1.3

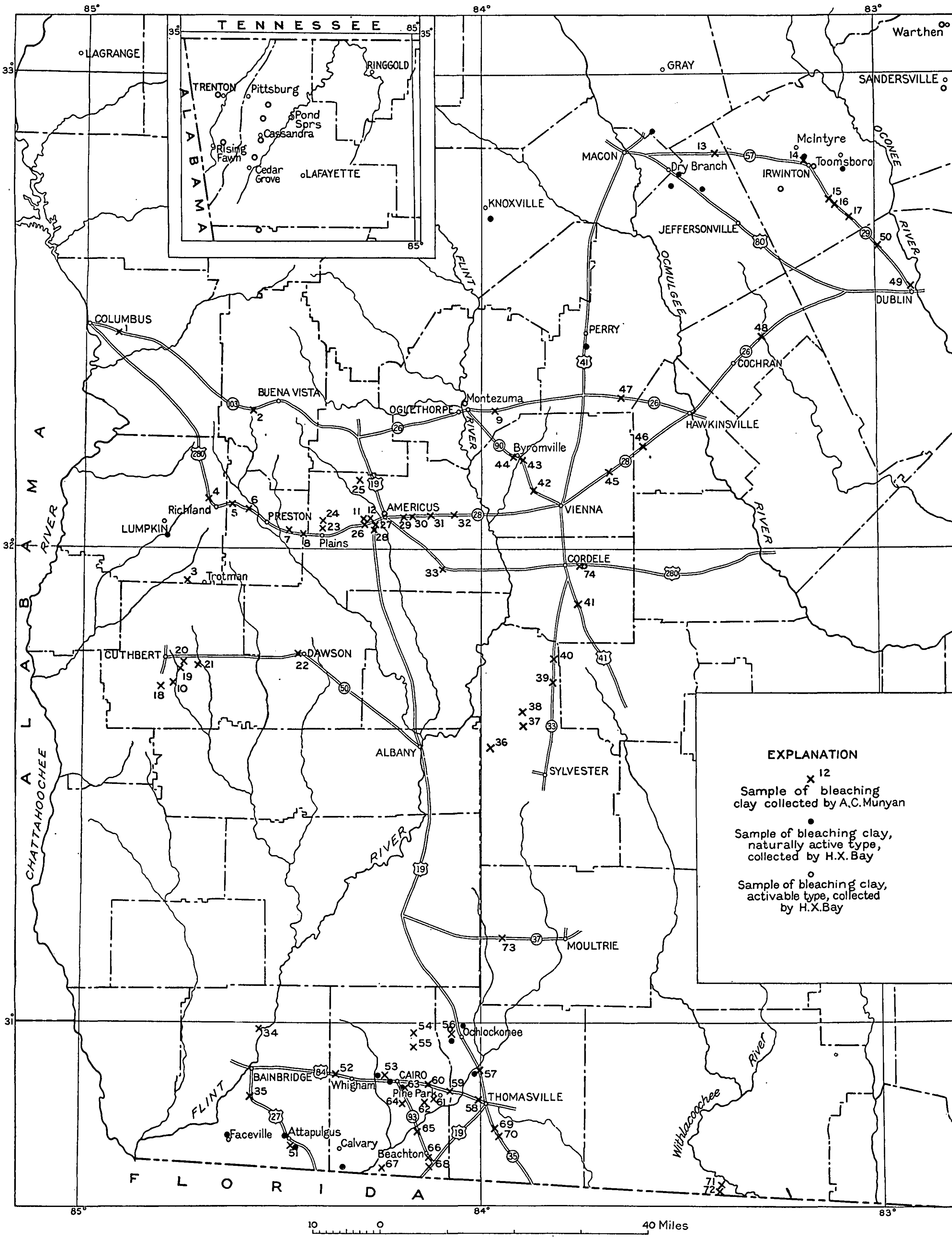
Although of the activable type, this clay has too little bleaching power to be of commercial interest.

Rising Fawn area.—A 2½-foot bed of bentonite is exposed in a road cut adjoining the property of Wesley Forrester, 1 mile south of Rising Fawn furnace and half a mile south of Cave Creek Church. The clay is soft and mealy, greenish gray, and somewhat sandy. It is underlain by a few inches of very sandy clay and then by thin-bedded bluish-gray limestone. The overlying beds are dense bluish limestones. The bentonite bed dips 12° N. 60° W.

Smith[54] gives the following chemical analysis for a "groove" sample from the exposure at this location:

Loss on ignition	12.61
Soda (Na_2O)	1.37
Potash (K_2O)	1.42
Lime (CaO)	7.59
Magnesia (MgO)	Trace
Alumina (Al_2O_3)	15.45
Ferric oxide (Fe_2O_3)	1.94
Titanium dioxide (TiO_2)	.27
Phosphorus pentoxide (P_2O_5)	.12
Silica (SiO_2)	59.77
	100.54

[54] Smith, R. W., op. cit., p. 336.



MAP OF PART OF GEORGIA SHOWING LOCALITIES TESTED.

Bleach ratings of three samples from the middle of the bed taken at intervals of 200 feet along the face of the exposure are as follows:

Sample	Raw				Acid-treated			
	G	Y	R	B	G	Y	R	B
1	0.5	0.5	0.6	0.6	0.9	1.3	1.5	1.6
2	.5	.6	.7	.8	.8	1.0	1.1	1.2
3	.4	.5	.6	.7	.9	1.2	1.3	1.4

This suite of samples has even lower bleach power than the average Ordovician bentonite and shows that the deposit is of no commercial importance as a bleaching clay for oils.

WALKER COUNTY

Bentonite crops out between steeply dipping beds of Chickamauga limestone along the foot of Lookout Mountain, in the Chattanooga Valley of Walker County. The linear extent of this bentonitic zone is several miles. (See pl. 7.) The northernmost exposure noted was on the property of Mrs. W. W. Scott, 1½ miles north of High Point station, and the bed was traced as far south as the Clem Hobbs farm, three-eighths of a mile north of Cedar Grove. Two bentonite beds occur in Walker County. The upper zone is best seen in the northern part of the county; the lower one is best developed southward from Cassandra.

Exposures of bentonite were examined near High Point station, Coopers Heights, Cassandra, and Cedar Grove.

High Point station.—The upper bentonite zone crops out on the properties of Mrs. W. W. Scott and J. J. Parrish, about 1½ miles north of High Point station on the Chattanooga Valley road. The clay is soft and mealy, white to greenish-gray, highly micaceous, sandy and limy. The maximum thickness is about 2½ feet. The associated beds consist of dense greenish-gray limestones which dip about 35° NW. The following chemical analysis of a sample of bentonite from the Parrish farm is given by Smith:[55]

Loss on ignition	5.80
Soda (Na_2O)	.82
Potash (K_2O)	1.94
Lime (CaO)	.14
Magnesia (MgO)	.27
Alumina (Al_2O_3)	21.80
Ferric oxide (Fe_2O_3)	7.04
Titanium dioxide (TiO_2)	.74
Phosphorus pentoxide (P_2O_5)	Trace
Silica (SiO_2)	61.52
	100.07

[55] Smith, R. W., op. cit., p. 338.

Bleach ratings of samples from the middle of the bentonite stratum on the Scott and Parrish farms are as follows:

	Raw				Acid-treated			
	G	Y	R	B	G	Y	R	B
Scott	0.6	0.7	0.8	0.8	1.1	1.7	1.8	2.0
Parrish	.6	.7	.7	.7	1.0	1.5	1.9	2.0

These samples are activable clay, but the bleaching efficiency is lower than that required for commercial bleaching clays. This occurrence is not of commercial importance.

Coopers Heights.—An exposure of bentonitic clay was examined on the property of Erskine Strickland, lot 94, 11th district, 4th section, half a mile west of Coopers Heights station on the Tennessee, Alabama & Georgia Railroad. A ditch beside the Coopers Gap road exposes 4 feet of gray to drab soft and mealy, highly micaceous sandy bentonitic clay, associated with limestone beds that dip 25° NW.

A series of three samples from the exposure on this property yielded the following bleach ratings:

	Raw				Acid-treated			
	G	Y	R	B	G	Y	R	B
Top	0.4	0.5	0.5	0.5	1.0	1.4	1.6	1.7
Middle	.5	.6	.6	.6	1.0	1.4	1.6	1.7
Base	.4	.5	.5	.5	.9	1.2	1.3	1.4

This clay has no commercial possibilities as a bleaching clay for oils.

Cassandra.—Several exposures of bentonite were noted in the vicinity of Cassandra station on the Tennessee, Alabama & Georgia Railroad. An exposure beside the road on the G. P. Baker property, 0.7 mile west of the Chattanooga Valley road and 0.8 mile north of Cassandra, on lot 131, 11th district, 4th section, shows both the upper and lower bentonitic zones of the Chickamauga limestone. The upper bed consists of 6 feet of greenish-gray soft and mealy, highly micaceous, slightly sandy and limy bentonitic clay. Below this and separated from it by several feet of bluish-gray limestone is a 4-foot bed of iron-stained greenish-gray unctuous, somewhat brittle, slightly sandy bentonite. The beds dip 30° N. 73° W. At this particular location no limestone shows above the bentonite horizon; the overlying material consists of red and gray plastic clay.

Smith [56] gives the following chemical anaylsis of a sample of bentonite from the upper bed:

[56] Smith, R. W., op. cit., p. 339.

Loss on ignition	6.06
Soda (Na_2O)	3.09
Potash (K_2O)	1.96
Lime (CaO)	.37
Magnesia (MgO)	.04
Alumina (Al_2O_3)	27.93
Ferric oxide (Fe_2O_3)	4.97
Titanium dioxide (TiO_2)	.74
Sulphur trioxide (SO_3)	Trace
Phosphorus pentoxide (P_2O_5)	.14
Silica (SiO_2)	54.69
	99.99

The bleach ratings of the two bentonite layers are given below.

Sample	Raw				Acid-treated			
	G	Y	R	B	G	Y	R	B
Upper bed:								
Top	0.6	0.8	0.9	1.0	0.9	1.4	1.5	1.6
Middle	.8	.9	.9	.9	1.0	1.6	1.8	1.9
Base	.6	.7	.8	.8	1.0	1.5	1.7	1.8
Lower bed:								
Top	.5	.6	.7	.7	.9	1.3	1.5	1.6
Middle	.5	.6	.6	.6	.6	1.0	1.2	1.3
Base	.5	.6	.7	.7	.9	1.4	1.6	1.8

Although the bleaching power of these clays is increased by partial acid leaching, the increase is not sufficient to bring them to commercial grade.

A 5-foot bed of bentonite at the lower horizon is exposed on the William and Thomas Coulter estate on the south side of Mill Creek, 1 mile southwest of Cassandra. The upper 2 feet of the bed consists of greenish-gray unctuous hard, brittle bentonite which grades downward (eastward) into soft and mealy clay. No limestone is showing above (west of) the bentonite, but thick beds of bluish-gray limestone are seen to occur below (to the east). The bentonite bed dips at an angle of 30°. The bleach ratings given below indicate that this material will not qualify as a commercial bleaching clay.

Sample	Raw				Acid-treated			
	G	Y	R	B	G	Y	R	B
Top	0.5	0.6	0.7	0.7	1.0	1.5	1.7	1.8
Middle	.6	.7	.7	.7	1.0	1.4	1.6	1.7
Base	.7	.8	.9	.9	1.0	1.4	1.6	1.7

The upper bentonitic stratum of the Chickamauga limestone crops out in a 6-foot exposure on the property of Dr. Walter Agnew, one-eighth of a mile west of the Chattanooga Valley road and 1.7 miles south of Cassandra. The bed consists of pale-green to greenish-gray unctuous, brittle, slightly sandy bentonitic clay. No limestone is visible either above or below the bentonite at this location. The overlying material is a red and brown sandy shale. The base was not exposed. The bentonite on the Agnew property is low in activable bleaching power and is not of commercial interest. The bleach rating is as follows:

Sample	Raw				Acid-treated			
	G	Y	R	B	G	Y	R	B
2 feet from top	0.6	0.8	0.9	0.9	0.7	1.0	1.3	1.5
4 feet from top	.4	.5	.5	.5	.6	1.0	1.1	1.2

The following section of bentonitic clay is exposed in a gully just west of the D. Hatfield house, in lot 277, 11th district, 4th section, 2.9 miles south of Cassandra:

	Ft.	in.
5. Clay, red, sandy, with a little interlaminated bentonitic clay at the base	10+	0
4. Bentonite, greenish gray, with dark-green streaks and ferruginous stains, unctuous, hard and brittle, very slightly sandy; breaks with conchoidal fracture	2	0
3. Bentonite, pale greenish gray, soft and mealy, very slightly sandy	2	6
2. Chert, dark green		6
1. Limestone, bluish gray.		

The bed dips 42° W. Bleach ratings of samples from beds 3 and 4 are as follows:

	Raw				Acid-treated			
	G	Y	R	B	G	Y	R	B
Bed 4	0.6	0.7	0.8	0.8	1.0	1.4	1.7	1.8
Bed 3	.4	.5	.5	.5	.7	1.1	1.4	1.5

This material is not sufficiently active after partial acid leaching to be of commercial interest as a bleaching clay for oils.

Cedar Grove area.—The lower bentonitic stratum crops out in a gully on the properties of W. S. Atkins and Clem Hobbs, in lots 313 and 314, 11th district, 4th section, three-eighths of a mile north of Cedar Grove. This represents the southernmost extension of the bentonite horizon examined in Walker County. The following section is exposed in the gully about 100 yards due west of the Atkins dwelling:

	Feet
5. Limestone, thin-bedded, gray, clayey	10+
4. Clay, gray to drab, partly siliceous, laminated, sandy	15
3. Bentonite, pale green, unctuous, hard and brittle, slightly sandy; becoming soft and mealy toward base	5
2. Chert, green	1
1. Limestone, gray.	

The bentonite bed dips 38° W. Bleach ratings are given below.

Sample	Raw				Acid-treated			
	G	Y	R	B	G	Y	R	B
Bed 4:								
Middle	0.6	0.7	0.8	0.8	0.6	0.7	0.8	0.8
Bed 3:								
Top	.3	.4	.4	.4	.6	.8	1.0	1.1
Middle	.4	.5	.6	.6	.6	1.1	1.5	1.6
Base	.6	.7	.8	.8	1.5	2.2	2.4	2.5

The sample from the base of bed 3 gives the highest bleach rating of all the materials sampled in Walker, Dade, and Chattooga Counties. This part of the bed approaches very nearly the commercial grade of bleaching clay, but the middle and upper parts are very poor. The clay overlying the bentonite is not activable.

EOCENE CLAYS

MIDWAY FORMATION

According to Veatch and Stephenson[57] the Midway formation of Georgia "occurs in a narrow belt, having a northeast-southwest trend, extending from Fort Gaines on Chattahoochee River to Montezuma on Flint River and thence a short distance into Houston County. * * * It is the surface formation over much of Clay, Quitman, Stewart, Randolph, Marion, Schley, Webster, and Macon Counties." The Midway formation has been described[58] as consisting of "ferruginous sand and local beds of white clay, together with fossiliferous limestone, marl, clay, and calcareous quartzite."

Locally the Midway formation is known to contain beds of low-grade fuller's earth. Materials of this type are well developed in Stewart County and probably occur elsewhere within the State. (See pl. 7.)

In 1917 the Lumpkin Mining Co. was organized for the purpose of developing a deposit of fuller's earth 5½ miles south of Lumpkin on the old Cuthbert road. This deposit is said to lie in lots 142, 143, and 149, 20th district, Stewart County. The company was reorganized as the Georgia Fuller's Earth Co. in 1920 and was controlled by the Columbia Chemical Co. in 1934. The property is owned by J. D. Singer and A. T. Fort, of Lumpkin, Ga. A milling plant was built at

[57] Veatch, J. O., and Stephenson, L. W., Geology of the Coastal Plain of Georgia: Georgia Geol. Survey Bull. 26, p. 219, 1911.
[58] Shearer, H. K., Bauxite and fuller's earth of the Coastal Plain of Georgia: Georgia Geol. Survey Bull. 31, p. 11, 1917.

the site of the proposed operation, and two pits were opened. Very little bleaching clay has been marketed from this deposit, and it was not in operation in 1934.

The deposit is said to cover about 800 acres and is estimated to contain about 4,000,000 tons. The clay is very similar in appearance to the Porters Creek clay, of Midway age, in Alabama, Mississippi, and elsewhere and may possibly be correlative with that formation.

The thickness is said to vary considerably within short distances but reaches a maximum of about 20 feet and probably averages about 10 feet. A section exposed in a pit just west of the milling plant shows about 15 feet of dull-gray to white (when dry) clay, which is more or less micaceous throughout, but especially so toward the base. The upper several feet is somewhat sandy. The entire section is highly jointed, and the joint-plane surfaces show iron stains. The material breaks with conchoidal fracture.

A suite of samples was taken from the pit face for laboratory testing. In the bleach ratings below, sample 1 represents the upper part of the 15-foot bed, No. 2 the middle section, and No. 3 the basal part.

Sample	Raw				Acid-treated			
	G	Y	R	B	G	Y	R	B
1	0.7	0.8	0.9	1.0	0.6	0.8	1.0	1.1
2	.6	.7	.7	.9	.5	.6	.8	.9
3	.5	.6	.7	.8	.6	.7	.8	.9

These samples are shown to be low-grade naturally active clays which are not greatly affected by acid treatment. The bleaching power of this Midway clay is inferior to that of the various fuller's earths being mined and marketed in other parts of the State, and therefore it cannot be expected to compete with the others.

BARNWELL FORMATION (TWIGGS CLAY MEMBER)

The lithologic character of the Barnwell formation has been described by Cooke and Shearer [59] as follows:

The greater part of the Barnwell formation is sandy, comprising widespread deposits of coarse brilliant-red sand which appears to derive its color from weathered glauconite, together with locally indurated beds of gray sandstone which in places approaches quartzite in texture, and basal conglomerates resembling the gravels of the Pleistocene terraces. The sand in many localities encloses masses of flint, many of which are fossiliferous and appear to represent the silicified remnants of limestone lenses.

The Twiggs clay member of the Barnwell consists typically of greenish-gray clay of low specific gravity, not plastic but breaking with hackly fracture and ex-

[59] Cooke, C. W., and Shearer, H. K., Deposits of Claiborne and Jackson age in Georgia: U. S. Geol. Survey Prof. Paper 120-C, p. 54, 1918.

hibiting all the properties of fuller's earth. The fuller's earth grades laterally into calcareous clay of similar appearance and properties and thence into argillaceous limestone. Some of the clay is free from grit, but most of it is interbedded with thin layers of sand.

According to Cooke and Shearer:[60]

The Barnwell formation occupies considerable areas in Burke, Richmond, Jefferson, Glascock, Washington, Wilkinson, Twiggs, and Houston Counties and smaller parts of adjacent counties. * * * The Twiggs clay member in eastern Georgia is confined chiefly to the northern edge of the area occupied by the Barnwell formation, but toward the west its outcrop widens until it practically coincides with that of the formation as a whole.

Concerning the distribution of the fuller's earth beds in the Barnwell formation, Shearer[61] writes:

Outcrops of fuller's earth and similar clays belonging to the Twiggs clay member of the Barnwell formation occur in a narrow belt extending more than half way across the State. The westernmost exposures are in Dooly County, and the belt continues northeastward to Savannah River near Augusta, with exposures in Houston, Crawford, Twiggs, Bibb, Bleckley, Wilkinson, Jones, Baldwin, Washington, Glascock, Jefferson, Burke, Richmond, and Columbia Counties.

During this investigation sections of the fuller's earth in the Twiggs clay member of the Barnwell were examined in Crawford, Houston, Jones, Twiggs, Washington, and Wilkinson Counties. Descriptions of these occurrences are given below. (See pl. 7.)

CRAWFORD COUNTY

A thick exposure of fuller's earth occurs in an outlier of the Barnwell formation on the property of Frank Matthis at Rich Hill, 4.5 miles southeast of Knoxville. The bed shows considerable variation within short distances, but the following section, measured in a gully on the south side of the hill, is more or less typical:

	Feet
3. Sand, dark red clayey with some thin clay laminations toward base	50
2. Clay, light greenish and yellowish gray to drab, unctuous, slightly limy at top and increasingly so toward base; lower few feet sandy and limy	20
1. Limestone, clayey	10+

Bleach tests of a suite of five samples from this 20-foot bed are shown below.

Sample	Raw				Acid-treated			
	G	Y	R	B	G	Y	R	B
Top	0.3	0.4	0.4	0.4	0.9	1.1	1.1	1.1
5 feet below top	.5	.6	.6	.6	1.3	2.0	2.2	2.3
10 feet below top	.5	.6	.6	.6	1.1	1.6	1.7	1.8
15 feet below top	.4	.5	.5	.5	1.1	1.7	1.8	1.8
Base	.5	.6	.6	.6	.5	.8	1.3	1.4

[60] Idem, p. 56.

[61] Shearer, H. K., Bauxite and fuller's earth of the Coastal Plain of Georgia: Georgia Geol. Survey Bull. 31, p. 158, 1917.

These samples show that the Twiggs clay at this location is not naturally active (fuller's earth) but is activable. The clay 5 feet below the top of the 20-foot bed nearly reaches commercial requirements for activable clay. The reaction of these clays to partial acid leaching perhaps suggests a derivation from ashy materials. The acid activability is very similar to that of the Ordovician bentonite of northwestern Georgia. This material is not of commercial importance.

HOUSTON COUNTY

An exposure of Twiggs clay was examined on the north slope of Mossy Hill, 5.4 miles south of Perry on U. S. Highway 41.

The exposed section shows 15 feet of tan to yellow-green thin-bedded fairly hard and brittle unctuous clay which overlies soft gray clayey limestone. A sample taken near the middle of the exposed section yielded the following bleach rating:

Raw				Acid-treated			
G	Y	R	B	G	Y	R	B
0.7	0.9	1.1	1.2	1.0	1.4	1.5	1.6

This material is shown to be a low-grade fuller's earth which meets the minimum requirements for commercial use and which at the same time is somewhat improved by partial acid leaching. This is a feature that would be expected to characterize activable clays which have been partly but not thoroughly leached by natural processes.

JONES COUNTY

A 10-foot exposure of fuller's earth occurs in a gully on the west side of the old Macon road 1 mile north of the Central of Georgia Railroad crossing and 9.5 miles southeast of Gray, in Jones County. The bed consists of tan to gray hard, brittle unctuous clay that breaks with conchoidal fracture. There are a few thin sand laminations near the top. The deposit appears to cover a considerable area and to lie beneath a relatively thin overburden. A bleach test of samples from this exposure resulted in the following ratings:

Sample	Raw				Acid-treated			
	G	Y	R	B	G	Y	R	B
Top	1.0	1.2	1.3	1.4	0.7	1.3	1.5	1.6
Middle	1.1	1.3	1.5	1.6	.6	1.0	1.2	1.3
Base	1.0	1.2	1.4	1.5	.7	1.0	1.2	1.4

The tests show these samples to be fuller's earth of good grade, which is not materially affected by acid treatment—a property that is common to many of the best naturally active clays of commercial grade.

The deposit lies within a mile of the Central of Georgia Railroad and may be reached by an all-weather wagon road. The quality and accessibility of the clay are favorable to commercial exploitation, and a further and more detailed exploration is warranted.

TWIGGS COUNTY

A detailed study of the Twiggs clay member of Shearer [62] showed that it changes considerably in character from north to south within Twiggs County. In the northern part, near Pikes Peak, are two well-defined beds of fuller's earth separated by about 50 feet of sand. The lower bed, with a maximum thickness of about 45 feet, is the thicker of the two. This bed is somewhat limy, especially toward the base. To the south the bed becomes thinner, with the thickening of the underlying limestone.

Pikes Peak area.—In the vicinity of Pikes Peak station on the Macon, Dublin & Savannah Railroad is a large high hill known as Pikes Peak. Numerous exposures of the Twiggs clay occur in this immediate area, and some of them are described below.

By far the best known occurrence of fuller's earth in this section of the State is that being mined by the General Reduction Co., of Macon. This company has been active in the Pikes Peak area since 1908. The original mine was northwest of Pikes Peak station, but the present operation is a short distance north of the station. The raw clay is shipped about 12 miles over the Macon, Dublin & Savannah Railroad to Macon for milling and preparation for market. It is reported that the General Reduction Co. controls many hundreds of acres underlain by clay in this area.

A 15-foot bed is now being mined. This is underlain by clay so interbedded and interlaminated with sand that it is not considered exploitable. The 15-foot bed carries a little interlaminated sand and is massively bedded. The clay is light gray, hard, brittle, and exceedingly unctuous. The entire clay section is highly jointed, and the joint planes bear stains of iron and manganese. Directly overlying the clay bed is a thin stratum of dark-gray, very plastic gumbolike clay. The overlying materials consist of varicolored clayey sands.

A series of samples taken in the western extension of the mine excavation yielded the following bleach ratings:

[62] Shearer, H. K., op. cit., pp. 164-165.

Sample	Raw				Acid-treated			
	G	Y	R	B	G	Y	R	B
Top	0.7	0.9	1.1	1.2	0.8	1.2	1.3	1.5
Middle	.6	.8	.9	1.0	.9	1.3	1.4	1.6
Base	.7	.8	1.0	1.1	.9	1.2	1.3	1.5

A discrepancy appears between this set of bleach ratings and that of a sample tested by P. G. Nutting, of the Geological Survey, at an earlier date. The previous rating was as follows:

Raw				Acid-treated			
G	Y	R	B	G	Y	R	B
0.9	1.2	1.3	1.6	0.8	1.1	1.4	1.8

The writer did not have the opportunity to procure additional samples for checking, and it is thought that the lower bleach rating of the 3-sample suite may illustrate the effect of oxidation in samples taken too near an old surface.

The following section was penetrated in a bore hole on the property of Peter Edge, near the abandoned grade of the Macon & Augusta Railroad, half a mile south of Stone Creek Church:

	Ft.	*in.*
5. Clay, red, sandy	3	3
4. Clay, greenish gray, slightly plastic, slightly sandy, micaceous and unctuous with considerable manganese stain	4	0
3. Same with interbedded red micaceous medium-grained sand	2	6
2. Clay, greenish gray, brittle, slightly micaceous, very sandy		5
1. Sand, gray, clayey, medium-grained.		

Bleach ratings of samples from beds 2 and 4 are given below.

Sample	Raw				Acid-treated			
	G	Y	R	B	G	Y	R	B
Bed 4:								
Top	0.6	0.7	0.8	0.9	1.3	1.7	1.9	2.1
Middle	.7	.9	.9	.9	1.0	1.5	1.6	1.8
Bed 2:								
Middle	.6	.7	.8	.9	1.0	1.2	1.4	1.8

The clay from the Edge property is not of commercial importance as bleaching clay for oil, but all the samples are materially improved by partial acid leaching.

A thick section of the Twiggs clay member is exposed in a gully on the property of Mrs. S. M. Dorsey, 300 yards north of Stone Creek

Church and about 1½ miles south of Dry Branch. The following section was measured at this locality:

	Feet
5. Clay, gray to drab, massively bedded, hard and brittle, unctuous, very slightly sandy; breaks with conchoidal fracture	10
4. Clay, mottled tan and gray, thin-bedded, slightly plastic, very unctuous, slightly sandy	5
3. Clay, gray to drab, massively bedded, hard and brittle, somewhat unctuous, slightly sandy	4
2. Same with interlaminated gray fine-grained sand	6
1. Sand, yellow to brown, micaceous, fine-grained.	

Samples were taken from beds 2, 3, 4, and 5 for laboratory tests. The bleach ratings are as follows:

Sample	Raw				Acid-treated			
	G	Y	R	B	G	Y	R	B
Bed 5, top	0.6	0.7	0.8	0.9	0.9	1.2	1.4	1.5
Bed 4, middle	.5	.6	.6	.6	1.4	1.9	1.9	1.9
Bed 3, middle	.6	.8	.9	1.0	.9	1.3	1.6	1.6
Bed 2, base	.5	.7	.7	.7	1.1	1.5	1.6	1.6

The clay at this locality may be classed as a noncommercial low-grade fuller's earth which is somewhat activable but not sufficiently so to make it commercially usable. Bed 4 which is the least efficient in the natural state, is the most activable. This section is assigned to the upper "fuller's earth" horizon of the Twiggs clay member.

A deep ravine a quarter of a mile northwest of Stone Creek Church and about 2¼ miles south of Dry Branch, on the property of Mrs. Lily Bowden, reveals the following section:

	Feet
5. Sand, red, clayey, medium-grained	20
4. Clay, pale greenish, sandy, with interlaminated and interbedded red fine-grained sand	50
3. Clay, pale greenish gray, hard and brittle, unctuous, slightly sandy	12
2. Like bed 3, with much interlaminated white micaceous fine- to medium-grained sand	30
1. Sand, gray, clayey, fine- to medium-grained.	

This section is thought to lie in the upper fuller's earth zone of the Twiggs clay. An interesting set of bleach ratings was obtained from tests of samples from this section, as follows:

Sample	Raw				Acid-treated			
	G	Y	R	B	G	Y	R	B
Bed 3:								
Middle	0.6	0.8	0.9	1.0	0.9	1.3	1.4	1.6
Bed 2:								
Top	No bleach raw				1.0	1.4	1.5	1.7
Middle	No bleach raw				1.1	1.8	1.9	2.0

Bed 3 is shown to be a low-grade fuller's earth that responds somewhat to acid treatment. Bed 2, although very similar in appearance to bed 3, shows no bleach in the natural state, but displays a fair degree of activability, which suggests an origin from ashy materials. Bed 3 may have been so leached by natural processes as to be fairly active in the natural state and can be only slightly improved by artificial leaching, whereas bed 2 is unleached and consequently is the most activable. Because of its low bleaching properties and its excessive overburden, this clay bed is not of commercial interest.

Twiggs clay is exposed in a ravine on the Lowe Wall property, 2 miles south of Pikes Peak. The full section of this upper clay zone is not exposed, but an outcropping bed shows 35 feet of yellowish-gray, fairly hard and brittle, unctuous, somewhat sandy clay with some interlaminated and interbedded fine-grained sand. The upper and lower fractions of the exposed section appear to be the most sandy. The bleach ratings of samples from this exposure are as follows:

Sample	Raw				Acid-treated			
	G	Y	R	B	G	Y	R	B
Top	0.6	0.8	0.9	0.9	1.1	1.5	1.7	1.8
10 feet below top	.6	.7	.8	.9	1.1	1.5	1.7	1.8
20 feet below top	.6	.7	.7	.8	1.1	1.5	1.7	1.9
30 feet below top	.6	.7	.8	.8	1.0	1.4	1.6	1.7

This clay is a low-grade fuller's earth that is materially improved by partial acid leaching. The bleaching property in both the naturally active and activable states does not meet commercial standards.

A sample from the middle of a 4-foot exposure in a gully on the property of Mrs. Kate Crump, 250 yards east of Stone Creek Church, yielded the following bleach rating:

Raw				Acid-treated			
G	Y	R	B	G	Y	R	B
0.7	0.8	0.9	1.0	0.8	0.9	1.0	1.1

This material is a low-grade fuller's earth and is probably not of commercial importance.

The lower "fuller's earth" zone of the Twiggs clay member crops out in a cut on the abandoned Macon & Augusta Railroad on the property of B. D. Tharpe, Sr., 2 miles south of Stone Creek Church. The entire thickness is unknown, as only 15 feet is exposed. The clay is pale greenish gray, hard, brittle, and unctuous, breaks with conchoidal fracture, and bears considerable manganese stain. Limy nodules are common throughout the exposed section. As shown in the following bleach ratings, this lower bed is very similar to the upper in its bleaching properties, being a low-grade fuller's earth that is considerably improved by partial acid leaching, although not sufficiently so to be of commercial importance.

Sample	Raw				Acid-treated			
	G	Y	R	B	G	Y	R	B
Top	0.6	0.7	0.8	0.9	0.9	1.3	1.5	1.6
Middle	.6	.7	.8	.9	1.0	1.3	1.6	1.8
Base	.6	.8	.9	1.0	.9	1.3	1.6	1.9

A single outcrop of the upper clay bed was examined in the southern extension of the Pikes Peak area. This exposure occurs in a gully on the property of Mose Sapp, 150 yards southeast of Stone Creek Church, where about 30 feet of greenish-gray, fairly hard and brittle, unctuous clay with interlaminated and interbedded sand may be seen. The lower section appears to be the most sandy. Bleach ratings of samples from this bed are given below.

Sample	Raw				Acid-treated			
	G	Y	R	B	G	Y	R	B
Top	0.6	0.7	0.8	0.9	1.1	1.5	1.6	1.7
Middle	.5	.7	.8	.9	1.1	1.6	1.8	1.9
Base	.8	1.0	1.1	1.3	1.1	1.7	1.9	2.1

This material is similar in bleaching properties to that occurring elsewhere in the Pikes Peak area and is of little commercial interest.

The upper clay bed of the Twiggs member was encountered in a bore hole on the property of R. M. Wood, 2 miles southeast of Fitzpatrick station on U. S. Highway 80. The hole was bored about 200 yards west of the Wood dwelling, where the following section was penetrated:

	Ft.	*in.*
11. Clay, red, sandy, plastic	1	0
10. Clay, greenish gray, hard and brittle, unctuous, slightly sandy	6	0
9. Sand, greenish gray, clayey, medium-grained	1	6
8. Clay, greenish gray, hard and brittle, unctuous, with interlaminated white fine-grained sand		6
7. Sand, greenish gray, clayey, medium-grained, with clay laminations		8
6. Clay, greenish gray, hard and brittle, unctuous, with occasional thin streaks of white fine-grained sand	1	8
5. Sand, greenish gray, clayey, medium-grained		6
4. Clay, greenish gray, unctuous, with thin clay laminations	3	1
3. Sand, greenish gray, clayey, medium-grained		6
2. Clay, greenish gray, hard and brittle, unctuous, slightly sandy	2	6
1. Clay and medium-grained sand, interbedded, greenish gray.		

Bleach ratings of auger samples from the above section are as follows:

Sample	Raw				Acid-treated			
	G	Y	R	B	G	Y	R	B
Bed 10:								
Top	0.4	0.6	0.6	0.6	1.1	1.5	1.5	1.5
Middle	.7	.9	1.0	1.2	.8	1.0	1.2	1.3
Bed 6, middle	.4	.5	.5	.5	1.1	1.5	1.5	1.5
Bed 4, middle	.6	.7	.8	.9	1.0	1.5	1.7	1.9
Bed 2, middle	.7	.9	1.0	1.1	.7	1.1	1.2	1.4

The irregularity in occurrence and the inferior bleaching power of this clay deposit is decidedly unfavorable to commercial development.

The lower clay bed was encountered in an auger hole on the farm of J. C. Miller, 1½ miles west of Fitzpatrick and about 500 yards south of the Macon, Dublin & Savannah Railroad. An auger hole about 300 yards west of a tenant house near the base of a hill penetrated 7½ feet of greenish-gray hard and brittle, unctuous, slightly sandy clay which bears scattered limy nodules near the top and which shows some manganese stain. The clay lies directly upon the Ocala limestone.

Three samples taken for laboratory testing had the following bleach ratings:

Sample	Raw				Acid-treated			
	G	Y	R	B	G	Y	R	B
Top	0.6	0.7	0.8	0.9	0.8	1.1	1.2	1.3
Middle	.6	.7	.8	.9	1.1	1.6	2.0	2.1
Base	.7	.9	1.0	1.1	1.4	2.1	2.6	2.7

The lower clay bed at this locality is shown to be a low-grade fuller's earth that is decidedly improved by partial acid leaching. The lower part of the 7½-foot bed approaches commercial grade as an activable clay. The clay bed here lies under an excessive overburden, so that this thin bed of activable clay probably could not be mined profitably. However, the fact that the basal part of the Twiggs clay member carries a commercial grade of activable clay at this place leads to the conclusion that more accessible deposits may occur elsewhere at this same horizon. A detailed investigation of the basal portion of the Twiggs member is to be recommended.

WASHINGTON COUNTY

The Barnwell formation of Washington County is described by Cooke and Shearer [63] as follows:

[63] Cooke, C. W., and Shearer, H. K., op. cit., p. 67.

The Barnwell formation is present throughout a large part of Washington County. The bed within the formation most easily recognized by its lithology is the fuller's earth of the Twiggs clay member, which, although discontinuous and variable in thickness, can be traced by a line of outcrops from Oconee across the county to Chalkner. The beds underlying the fuller's earth average about 50 feet in thickness and consist chiefly of calcareous clay and sand, with locally indurated beds of quartzite containing a characteristic lower Jackson fauna. Above the Twiggs clay member is red sand with lenses of impure limestone.

During the course of this investigation sections of the Twiggs clay were examined in the Sandersville and Warthen areas.

Sandersville area.—Five feet of greenish gray, fairly hard and brittle, unctuous, sandy clay interlaminated with fine sand near the top is exposed in a road cut along State Highway 24, 5.8 miles west of Sandersville. The following bleach rating was derived from a sample taken near the middle of this exposed section:

Raw				Acid-treated			
G	Y	R	B	G	Y	R	B
0.7	0.9	1.0	1.1	1.0	1.4	1.8	1.9

This is a low-grade fuller's earth which is also activable, but the bleaching power of this clay in either form is below commercial grades.

The following section is exposed in a road cut adjoining the property of Mrs. Eugene Harris, 2.2 miles west of Sandersville on State Highway 24 and 0.2 mile west of Limestone Creek:

	Feet
3. Sand, red, clayey, medium- to coarse-grained	15
2. Clay, light gray, hard and brittle, sandy, with interlaminated micaceous fine-grained sand	12
1. Clay, tan, waxy, distinctly unctuous, with interbedded red coarse-grained sand	10+

A sample from the sand-free portion of bed 1 yielded the following bleach rating:

Raw				Acid-treated			
G	Y	R	B	G	Y	R	B
0.7	0.8	0.9	0.9	1.2	1.7	1.8	1.9

This clay is more closely related to the activable type of bleaching clays than to the naturally active class. The clay fraction of bed 1 resembles bentonitic clay in appearance. Weathered surface material is not a commercial bleaching clay for oils.

An 8½-foot bed of light greenish-gray, hard and brittle, unctuous, thick-bedded, slightly sandy clay with some interstratified fine sand crops out in a gully on the property of Walter Harris 3½ miles west of Sandersville on State Highway 24 and half a mile south on a county road. The extent of the bed is unknown, but it is thought to cover a considerable area. The overlying beds consist of clayey sands and sandy clays and probably range from 15 to 50 feet in thickness.

Samples taken from the top, middle, and basal portion of the exposed section for bleach tests gave the following results:

Sample	Raw				Acid-treated			
	G	Y	R	B	G	Y	R	B
Top	0.7	0.9	1.0	1.1	1.1	1.8	2.1	2.2
Middle	.8	1.0	1.1	1.2	1.2	1.8	2.1	2.2
Base	.9	1.1	1.3	1.4	1.0	1.9	1.9	2.0

The middle and lower parts of this bed qualify as commercial fuller's earth, with the bleaching efficiency increasing toward the base. At the same time the entire section is activable but falls short of commercial requirements for activable clay. The behavior of this clay suggests a material of the bentonitic type which has been partly but not thoroughly leached by natural processes. The deposit on the Harris property is thought to warrant further detailed prospecting.

Warthen area.—A good exposure of the Twiggs clay member occurs on the property of W. J. Norris, on Gin Pond Creek, 2½ miles west of Warthen. The section here is as follows:

	Feet
5. Sand, massively bedded, red	30
4. Clay, pale green, plastic, sandy	2
3. Clay, brownish gray, laminated, hard and brittle, unctuous, grit-free	12
2. Clay, pale green, plastic, sandy	9
1. Clay, greenish gray, very sandy.	

Bed 3 differs from much of the clay elsewhere in the Twiggs member in that it is absolutely free of grit. Bleach ratings of samples from this bed, given below, indicate that it is a good grade of fuller's earth and well within the commercial range of naturally active bleaching clay.

Sample	Raw				Acid-treated			
	G	Y	R	B	G	Y	R	B
Top	0.9	1.2	1.3	1.4	1.0	1.5	1.8	2.0
Middle	1.0	1.3	1.5	1.8	1.0	1.5	1.6	1.7
Base	1.0	1.3	1.4	1.5	1.0	1.4	1.6	1.8

The clay bed on the Norris property is thought to cover a considerable area, with an overburden having a maximum thickness of about 40 feet but averaging considerably less. Much of the clay probably lies within the valley of Gin Pond Creek, where the overburden would be slight. The section described above is within a mile of the Augusta & Savannah Railroad. Further prospecting is recommended for this deposit of clay.

WILKINSON COUNTY

According to Cooke and Shearer,[64]

In Wilkinson County the Twiggs clay member is less persistent and less pure than in Twiggs County, and the material is generally too sandy or calcareous to serve as a commercial fuller's earth. Locally both limestone and fuller's earth are absent, and the Barnwell formation consists entirely of red sand with a few thin beds of plastic clay or gumbo.

Exposures of the Twiggs clay member were examined in the general areas of Irwinton and Toomsboro, and descriptions of these are given below.

Irwinton area.—A road cut on the Jeffersonville-Irwinton road 13½ miles northeast of Jeffersonville reveals the following section:

	Feet
3. Sand, red, clayey, medium-grained	20
2. Clay, gray, laminated, fairly hard and brittle, unctuous, with occasional fine micaceous sand partings and considerable manganiferous stain	5
1. Like bed 2, with interbedded sand	5+

Bleach ratings derived from samples taken from beds 1 and 2 are as follows:

Sample	Raw				Acid-treated			
	G	Y	R	B	G	Y	R	B
Bed 2:								
Top	0.8	1.0	1.2	1.3	1.1	1.5	1.6	1.7
Middle	.7	.9	1.1	1.2	1.5	2.5	2.7	3.0
Bed 1, middle	.8	1.2	1.3	1.4	1.1	1.6	1.7	1.9

This entire clay section is a low-grade fuller's earth, and the middle of bed 2 is an activable clay of commercial grade. This bed warrants further study.

A low-grade commercial fuller's earth is exposed in a road cut along State Highway 29, 1 mile southwest of Irwinton, where 7 feet of light-gray laminated, somewhat sandy clay and interbedded micaceous sand crops out in a ditch. The bed is overlain by red clayey sand about 25 feet thick. A sample taken from the middle of the exposure and typical of the less sandy phase yielded a bleach rating that meets the lowest requirements for commercial clays. The rating is as follows:

[64] Cooke, C. W., and Shearer, H. K., op. cit., p. 70.

Raw				Acid-treated			
G	Y	R	B	G	Y	R	B
0.8	1.0	1.2	1.3	1.0	1.5	1.7	1.8

An 8-foot bed of Twiggs clay crops out in a road cut 2 miles east of Irwinton on the Ball Ferry road. This bed consists of greenish-gray hard and brittle, unctuous, slightly sandy clay. The upper 2 feet appears to be somewhat less sandy than that below. Directly overlying this bed is a 1-foot layer of light-gray, sandy plastic, gumbo-like clay which in turn is overlain by 15 feet of red medium-grained clayey sand that bears a few small rounded quartz pebbles. Samples from this 8-foot exposure yielded the following bleach ratings:

Sample	Raw				Acid-treated			
	G	Y	R	B	G	Y	R	B
2 feet from top	0.5	0.6	0.6	0.6	1.5	2.5	2.7	2.9
5 feet from top	.6	.8	1.0	1.1	1.5	2.1	2.3	2.4
8 feet from top	.5	.7	.8	.9	1.4	1.9	2.0	2.1

Although of little interest as a naturally active clay, this material activates sufficiently to bring a part of the bed within the commercial range of activable clays. The upper part of the bed, which is the least sandy, is the most activable. Activability appears to decrease with depth. This part of the Twiggs clay member is sufficiently activable to warrant a detailed investigation in this immediate locality. It is probable that unweathered samples would prove even higher in activable bleaching properties.

In 1931 Marvin Hall opened a mine in the Twiggs clay on the property of J. T. Stevens, Sr., 7½ miles northeast of Irwinton. Since that time a relatively small tonnage of fuller's earth has been produced and shipped. It is reported that most of the output goes into the vegetable-oil trade. The clay is milled at a plant at McIntyre. The following section is exposed in the mine excavation:

	Feet
5. Sand, red, clayey	40
4. Clay, gray, hard and brittle; interbedded with coarse-grained sand	4
3. Clay, greenish gray, slightly sandy, hard and brittle, unctuous with occasional partings of micaceous fine-grained sand	10
2. Sand and clay, interbedded, greenish gray	3
1. Clay, dark bluish gray, micaceous, somewhat sandy, calcareous, very hard and brittle, with occasional thin streaks of bluish-gray clayey limestone and shell fragments, which increase toward the base	10+

The bleach ratings of samples from beds 1 and 3 are given below.

Sample	Raw				Acid-treated			
	G	Y	R	B	G	Y	R	B
Bed 3: 5 feet from top	0.7	0.8	0.8	0.9	1.2	1.8	1.9	2.0
Bed 1:								
Top	.6	.9	1.1	1.2	1.0	1.3	1.4	1.4
2 feet from top	.6	.9	1.1	1.2	1.0	1.3	1.3	1.4
4 feet from top	.6	.9	1.1	1.2	.8	1.0	1.1	1.1
6 feet from top	.9	1.1	1.3	1.4	.9	1.1	1.2	1.2
8 feet from top	.7	.8	.9	.9	.7	.9	1.0	1.0

The present production comes from bed 1. This clay seems to be fairly uniform in bleaching properties throughout the section, save for the lower 2 feet, which is considerably less efficient than the rest. The bleaching efficiency is little changed by acid leaching.

A sample of fuller's earth from the Carswell property, between Irwinton and McIntyre, was submitted to the Geological Survey by F. H. Opper, Inc., of Savannah, Ga. This company reports an extensive deposit of fuller's earth which reaches a thickness of 49 feet in the northeast section of lot 110, 4th district, in Wilkinson County. The clay is described as being "very light in color and light enough to float in water." The company reports additional occurrences on the property of L. E. Pace, about 1½ miles west of McIntyre, and on the lands of the Edgar Bros. Co., near Deidrich.

The sample submitted from the Carswell property yielded the following bleach rating:

Raw				Acid-treated			
G	Y	R	B	G	Y	R	B
1.0	1.2	1.4	1.5	1.1	1.6	1.8	2.1

This sample is a good grade of fuller's earth, which is slightly improved by acid leaching.

Toomsboro area.—The following section of the Twiggs clay member was encountered in a bore hole on the west side of the H. J. Ivey estate, 3.9 miles southeast of Toomsboro:

	Feet
6. Clay, red, sandy	1
5. Clay, greenish gray to tan, sandy, micaceous, fairly soft	4
4. Like bed 5 but hard and brittle	2
3. Like bed 5 but with less admixed sand and with occasional sand laminations	2
2. Clay, interbedded with greenish gray, hard and brittle, gray medium-grained sand with limy nodules	4
1. Marl, soft, tan.	

Samples were taken from beds 2, 3, 4, and 5 for laboratory testing and the following bleach ratings resulted:

Sample	Raw				Acid-treated			
	G	Y	R	B	G	Y	R	B
Bed 5, 1 foot from top	0.7	0.8	0.9	1.0	0.8	1.3	1.5	1.6
Bed 4, 1 foot from top	.7	.9	1.0	1.1	1.0	1.5	1.8	1.9
Bed 3, 1 foot from top	.7	.9	1.1	1.2	1.1	1.6	1.9	2.0
Bed 2, 2 feet from top	.5	.6	.7	.8	.6	.9	1.1	1.2

These samples represent a very low-grade fuller's earth which is somewhat improved in bleaching efficiency by acid treatment. This material has no commercial significance as a bleaching clay for oils.

An extensive deposit of clay of the fuller's earth type occurs on the properties of Ben Lavender, L. N. Meredith, and Mrs. Charles Lord, about 2 miles northeast of Toomsboro. A ravine on the north side of the Lavender farm shows some 25 feet of dark-blue hard and brittle, somewhat sandy, micaceous and fossiliferous clay. The owner reports that a bore hole located at the base of the exposed section penetrated an additional 50 feet of clay.

A suite of three samples collected from the top, middle, and base of the exposed section gave the following bleach ratings:

Sample	Raw				Acid-treated			
	G	Y	R	B	G	Y	R	B
Top	0.7	0.9	1.0	1.1	1.1	1.7	2.0	2.2
Middle	.7	.9	1.1	1.2	.7	1.0	1.1	1.2
Base	1.0	1.3	1.5	1.5	.9	1.3	1.5	1.7

The sample from the base of the exposure on the Lavender farm is shown to be sufficiently active to be classed as a commercial fuller's earth, but the middle and upper parts are inferior in quality.

Between 1915 and 1920 a small amount of clay was mined and marketed from a deposit on the farm of S. B. Gilbert, 4 miles northeast of Toomsboro. This clay is dark blue and is somewhat sandy, micaceous, and fossiliferous. The material exhibits conchoidal fracture. A bleach test of a sample from a protected stock pile (see below) proved it to be low in bleaching power and not equal to the standards proposed in connection with this investigation for commercial clay. (See p. 15.)

Raw				Acid-treated			
G	Y	R	B	G	Y	R	R
0.7	0.8	0.9	1.0	0.8	1.3	1.5	1.7

A 3-foot bed of bluish-gray laminated micaceous sandy clay is exposed in a gully on the property of T. H. McIntosh, 1.8 miles south of Toomsboro. A sample from the top of this exposure showed this clay to be a low-grade fuller's earth which has no commercial significance. The bleach rating is as follows:

Raw				Acid-treated			
G	Y	R	B	G	Y	R	B
0.6	0.9	1.0	1.1	0.7	0.9	1.0	1.1

OLIGOCENE CLAYS

FLINT RIVER FORMATION

The beds of Vicksburg age in Georgia (now called the Flint River formation) have been described [65] as consisting principally of bright-red clayey sand, which is largely residual and shows no trace of stratification. Fossiliferous chert fragments and ledges derived from the complete silicification of thin beds of limestone are common. Associated with the red clayey sand are beds of bentonitic clay that are irregular in occurrence and distribution. These beds consist of iron-stained pale-green to greenish and light-gray unctuous, plastic to hard and brittle or soft and mealy, more or less sandy clay. The clay is of the activable bleaching type, and weathered samples compare favorably in bleaching qualities with the Ordovician bentonites of the northwestern part of the State. Although no volcanic-ash structure has been reported from this material, its appearance and acid activability suggest a derivation from ash, and it is possible that these beds are correlative with the extensive bentonite zone in the Vicksburg of Mississippi and elsewhere. The writer had very little time for the study of the clays of Vicksburg age in Georgia, but Mr. Munyan later visited and sampled some of the areas occupied by these clays. His results are given on pages 295–297 of this report.

The Oligocene Flint River formation in Georgia has been mapped by Cooke [66] as extending southwestward from the Oconee River in Laurens County across Pulaski, Dooly, and Sumter Counties, where the outcrop divides. One tongue roughly follows the course of the Flint River in a narrow belt across Crisp, Dougherty, Mitchell, Grady, and Decatur Counties. The other tongue trends southwestward in a broken belt of outcrops through Terrell, Randolph, Calhoun, and Early Counties. The most extensive development appears to be in the upland areas of Pulaski, Dooly, and Sumter Counties.

[65] Cooke, C. W., Am. Assoc. Petroleum Geologists Bull., vol. 19, p. 1170, 1935. Shearer, H. K., op. cit. p. 16.
[66] Geologic map of the United States, U. S. Geol. Survey, 1932.

Exposures of clay in the Flint River formation were examined by the writer in Crisp, Dooly, and Macon Counties. (See pl. 7.) A sample from this horizon in Sumter County was submitted to the Geological Survey for examination.

CRISP COUNTY

A rather extensive deposit of clay occurs on the property of Law & Co., 2.4 miles east of Cordele on U. S. Highway 280, Crisp County. This may belong in the Hawthorn formation rather than in the Oligocene.

The following section was penetrated in a bore hole in the southeastern part of the property:

	Ft.	*in.*
7. Clay, iron-stained, gray, highly sandy, slightly micaceous	10	0
6. Same, but more micaceous	3	0
5. Same, but dark red	4	0
4. Sand, brown, micaceous, slightly clayey, medium- to coarse-grained	1	6
3. Clay, gray, very slightly micaceous, somewhat sandy	4	6
2. Same with increase in sand admixture	3	0
1. Sand, brown, micaceous, slightly clayey, medium- to coarse-grained.		

Bleach ratings of samples from beds 2, 3, 5, 6, and 7 are given below.

Sample	Raw				Acid-treated			
	G	Y	R	B	G	Y	R	B
Bed 7:								
4 feet from top	1.1	1.2	1.3	1.3	1.4	2.1	2.2	2.3
8 feet from top	1.0	1.1	1.1	1.1	1.5	1.9	2.1	2.2
Bed 6, 2 feet from top	1.0	1.1	1.2	1.2	1.5	2.1	2.2	2.3
Bed 5, 3 feet from top	.8	.9	.9	.9	1.5	2.2	2.5	2.6
Bed 3, 2 feet from top	.4	.5	.5	.5	1.2	1.5	1.5	1.5
Bed 2, 1 foot from top	.5	.6	.6	.6	1.5	1.6	1.6	1.6

The bleaching properties of the clay in this section vary greatly and parts of beds 1 and 2 qualify as commercial naturally active clays which are considerably improved by partial acid leaching. Bed 5 is sufficiently activable to be of commercial interest.

Another bore hole on this property was put down near the right of way of the Atlanta, Birmingham & Coast Railroad, where the following section was revealed:

	Ft.	*in.*
4. Clay, red, sandy	1	0
3. Clay, iron-stained, gray, tough and plastic, very sandy	4	0
2. Clay, greenish gray, somewhat sandy, slightly plastic, streaked with brown fine-grained sand	1	6
1. Clay, light gray, mealy, more or less sandy	20	

Bleach ratings of samples from beds 1 and 3 are given below.

Sample	Raw				Acid-treated			
	G	Y	R	B	G	Y	R	B
Bed 3, 3 feet from top	0.6	0.7	0.7	0.7	1.1	1.5	1.6	1.6
Bed 1:								
2 feet from top	.6	.6	.6	.6	1.3	1.9	2.0	2.0
6 feet from top	.6	.7	.7	.7	1.3	1.3	1.3	1.3
10 feet from top	.6	.7	.7	.7	1.4	2.0	2.1	2.2
19 feet from top	.6	.7	.7	.7	1.7	2.2	2.3	2.3

The clay from this section has only slight bleaching power in the natural state but is brought near the commercial grade by partial acid leaching.

Careful prospecting might reveal some parts of this deposit that could be classed as activable clay of commercial grade. The deposit is readily accessible, as it is bisected by the Atlanta, Birmingham & Coast Railroad. The clay bed reaches a thickness of about 25 feet, and the overlying beds are very thin. The deposit probably covers an area of about 150 acres.

DOOLY COUNTY

A 6-foot bed of gray sandy, somewhat mealy clay thought to be of Flint River age crops out in a road cut 0.4 mile south of Turkey Creek on the Vienna-Montezuma road (State Highway 90). The clay bed is overlain by about 15 feet of red clayey sand that contains many small iron concretions. A sample taken near the top of the exposed section resulted in the following bleach rating:

Raw				Acid-treated			
G	Y	R	B	G	Y	R	B
0.5	0.6	0.6	0.6	1.0	1.7	1.8	1.8

The material is fairly activable, but this particular sample is not sufficiently so to be of commercial interest as a bleaching clay for oil.

MACON COUNTY

Clays similar to those described above have been reported to occur along the Atlanta, Birmingham & Coast Railroad south of Montezuma, in southern Macon County.

A bed of iron-stained gray, tough and brittle sandy clay that reaches a thickness of about 30 feet crops out on a hillside 8½ miles northwest of Oglethorpe on State Highway 90. This material is very similar to that described from Dooly County and is also overlain by red clayey sand which contains many small iron concretions. A sample taken near the top of this exposed section gave the following bleach rating:

Raw				Acid-treated			
G	Y	R	B	G	Y	R	B
0.7	0.8	0.9	0.9	1.1	1.8	1.9	2.0

This sample is of the activable type but the bleaching power is below commercial grade.

SUMTER COUNTY

Lane Mitchell, then a member of the Georgia Geological Survey, submitted a sample of greenish-gray unctuous, somewhat sandy clay from an exposure on the property of W. R. Hansford, about 1½ miles south of Americus on United States Highway 19. The clay is associated with red sand and silicified limestone and is probably of Flint River age. This sample gave the following bleach rating:

Raw				Acid-treated			
G	Y	R	B	G	Y	R	B
0.7	0.8	0.8	0.8	1.2	1.7	2.1	2.4

This material when acid-treated closely approaches the bleaching properties of commercial clay, and unweathered samples would very probably yield higher bleach ratings. It is thought that considerable quantities of clay of this type occur in the vicinity of Americus and a thorough investigation is recommended for this area.

Similar clays are known to crop out along United States Highway 19 a few miles north of Americus and also west of that place on the Americus-Vienna highway.

MIOCENE CLAYS

HAWTHORN FORMATION

The Hawthorn formation in Georgia has never been formally described under that name. Veatch and Stephenson's Alum Bluff formation, Marks Head marl, and part of their Altamaha formation [67] have been found to be an extension of the Hawthorn formation of Florida.

The Hawthorn formation in Georgia is generally light-colored. It contains much fine sand mingled with white clay, also coarse sand and angular gravel. Parts of it are hardened to sandstone. Associated with the sands and clays are beds of drab, gray, and greenish-gray fuller's earth.

[67] Veatch, J. O., and Stephenson, L. W., Geology of the Coastal Plain of Georgia: Georgia Geol. Survey Bull. 26, pp. 342–366, 400–423, 1911.

The Hawthorn formation occupies a broad hilly belt (Tifton upland or "wire-grass region") that extends from the Florida line to Waynesboro and lies between the lowlands bordering the Flint River (Dougherty plain) and the coastal terraces. It underlies the terrace deposits and is exposed in some of the valleys that cut through them.

DECATUR COUNTY

The Hawthorn formation is extensively developed in the part of Decatur County southeast of the Flint River. (See pl. 7.) By far the largest deposits of fuller's earth are in the southern part of the county, especially in the vicinity of Attapulgus and Little Attapulgus Creeks, where a large producer of fuller's earth—the Attapulgus Clay Co.—has extensive operations.

The Attapulgus Clay Co., with its mill and offices at Attapulgus, Ga., has been very active in this area for several years and is reported to control many hundred acres of fuller's earth in Decatur County. The production figures are not available, but the yearly tonnage is known to be large.

At the present time this company is producing clay from a deposit some 4 miles west of Attapulgus. The part of the fuller's earth bed now worked has an average thickness of 8 to 10 feet, and the overburden of clayey sand reaches a maximum of about 75 feet. The modern equipment employed in mining makes the removal of thick overburden feasible, and thicknesses of as much as 50 feet of overlying beds are sometimes taken off to reach a comparatively thin bed of fuller's earth.

The fuller's earth is light to greenish gray, unctuous, hard, and brittle. Where the overburden is thick the bed contains lenses of hard clayey limestone and small masses of crystalline calcite. Directly overlying the productive layer is a thin bed of gray, plastic, gumbolike clay that is removed with the overburden.

Two suites of samples collected from the working face of the mine excavation yielded the following bleach ratings:

Sample	Raw				Acid-treated			
	G	Y	R	B	G	Y	R	B
Suite 1:								
Top	0.9	1.1	1.2	1.3	0.9	1.1	1.2	1.3
Middle	.9	1.1	1.2	1.3	.9	1.1	1.2	1.3
Base	.9	1.1	1.2	1.4	.9	1.1	1.2	1.3
Suite 2:								
Top	.9	1.2	1.4	1.6	.7	.8	.8	1.4
Middle	.9	1.1	1.3	1.5	.6	1.0	1.5	1.5
Base	.9	1.0	1.1	1.2	.6	.7	.7	.9

The bleach ratings show the uniformly good quality of this section of the Hawthorn fuller's earth. Unlike the fuller's earth of the

Barnwell formation, this material is not improved in bleaching power by acid treatment, and some of it is even lowered.

A 6-foot bed of light-gray, mealy, very sandy fuller's earth is exposed in a road cut 2 miles south of Attapulgus on the Amsterdam road. This bed is overlain by a few feet of gray plastic sandy clay and a considerable thickness of red clayey sand. A sample from the middle of the 6-foot bed gave the following rating:

Raw				Acid-treated			
G	Y	R	B	G	Y	R	B
1.1	1.3	1.4	1.4	0.7	1.0	1.2	1.3

The bleaching properties of this clay are very similar to those of the material described above.

Deep ravines on the properties of Thomas Crowley and J. R. Slater, about half a mile west of the Atlantic Coast Line station at Faceville, reveal thin beds of fuller's earth. An auger hole on the Crowley property encountered the following section:

	Feet
5. Clay, brown, sandy	2
4. Fuller's earth, gray, hard, very sandy, becoming dark blue 1 foot from top	3
3. Clay, dark blue, very hard and dense, waxy and unctuous	3
2. Like bed 3 but very sandy	1
1. Sand, medium gray, hard, clayey, medium- to fine-grained	4

On the Slater property, some 300 yards west of that described above, the following section was revealed in an auger hole.

	Feet
5. Sand, red	1
4. Fuller's earth, greenish gray, somewhat hard and brittle, sandy	2
3. Same, but more sandy and micaceous	4
2. Fuller's earth, sandy interbedded with hard sand	4
1. Sand, gray, hard, medium-grained.	

Bleach ratings of auger samples from the Crowley and Slater properties are given below.

Sample	Raw				Acid-treated			
	G	Y	R	B	G	Y	R	B
Crowley farm:								
Bed 4, 1 foot from top	0.8	1.1	1.2	1.3	0.7	0.8	0.8	1.1
Bed 3, 1 foot from top	1.0	1.3	1.4	1.5	.6	.7	.7	.9
Slater farm:								
Bed 4, 1 foot from top	.8	1.0	1.1	1.2	.6	.8	.9	1.0
Bed 3:								
2 feet from top	.9	1.1	1.2	1.3	.7	.8	.9	1.0
3 feet from top	.8	1.1	1.3	1.4	.6	.8	.9	1.0

As shown by the bleach ratings, fuller's earth of good quality occurs on the Crowley and Slater farms. The clay beds are intermixed with sands that would be a serious obstacle to mining. The fuller's earth bed can be reached only in the deep ravines, and for the most part the clay is covered by an overburden that exceeds 100 feet. The area is of little commercial interest.

GRADY COUNTY

Bleaching clays crop out in the central and southern parts of Grady County. Preliminary investigations were made in the areas of Tired and Little Tired Creeks, in the central part of the county, and near Calvary, in the southern part.

Tired Creek area.—Fuller's earth was encountered in bore holes on the property of H. J. Parrish, 4.3 miles west of Cairo and about half a mile north of United States Highway 84, along Tired Creek. The following section was encountered in an auger hole on this property and is thought to be representative:

	Feet
7. Clay, iron-stained, gray, plastic, sandy	5
6. Sand, gray, clayey, medium-grained	3
5. Clay, light gray, sandy	1
4. Clay, gray, somewhat plastic, unctuous, slightly sandy	4
3. Clay, light gray, hard and brittle, unctuous, very slightly sandy commonly with manganese stain	3
2. Like bed 3 but very sandy	1
1. Sand, gray, clayey, medium-grained.	

Samples from beds 3 and 4 were subjected to oil bleach tests, and the following ratings were derived:

Sample	Raw				Acid-treated			
	G	Y	R	B	G	Y	R	B
Bed 4:								
1 foot from top	0.7	0.8	0.8	0.8	1.0	1.5	1.6	1.6
3 feet from top	.4	.5	.5	.5	1.1	1.2	1.2	1.2
Bed 3:								
1 foot from top	.6	.8	.9	.9	.6	.8	.9	1.0
3 feet from top	.6	1.1	1.2	1.2	.5	.7	.9	1.2

Bed 4 is a clay of the activable type, whereas bed 3 is naturally active. Neither of the two is sufficiently active to be of commercial interest.

A 4½-foot bed of very hard and brittle pale greenish-gray, slightly sandy fuller's earth was reached in an auger hole about a quarter of a mile south of that described above. This material is a good naturally active clay, and its bleaching action is comparable to that of the commercial fuller's earths. Bleach ratings of samples from the upper, middle, and lower parts of this bed are given on the following page.

Sample	Raw				Acid-treated			
	G	Y	R	B	G	Y	R	B
Top	1.1	1.2	1.3	1.4	0.5	0.6	0.7	0.8
Middle	1.0	1.3	1.5	1.7	.6	.7	.8	.9
Base	1.0	1.3	1.5	1.6	.5	.6	.7	.8

The clay on this property is thought to be of little commercial significance, owing to the variation in bleaching efficiency and to the small thickness of the beds.

The following section is exposed in a road cut along United States Highway 84, 4.3 miles west of Cairo and just east of Tired Creek:

	Feet
4. Sand, red, clayey	4
3. Clay, light gray, hard and brittle, sandy	8
2. Like bed 3, but very sandy	1
1. Sand, indurated, white.	

The following bleach ratings were derived from samples obtained from beds 2 and 3:

Sample	Raw				Acid-treated			
	G	Y	R	B	G	Y	R	B
Bed 3:								
1 foot from top	0.7	1.0	1.1	1.1	0.6	0.9	1.1	1.4
5 feet from top	.7	.9	1.0	1.0	.6	.9	1.0	1.2
Bed 2, 6 inches from top	.6	.7	.7	.7	.7	1.3	1.4	1.6

This clay is not sufficiently active to be of commercial interest as a bleaching agent for oils.

A prospect hole on the property of R. B. Roddenbery, in the valley of Tired Creek about a quarter of a mile north of the exposure described above, penetrated the section described below.

	Feet
5. Sand, brown, clayey, fine-grained	3
4. Clay, gray, plastic, sandy	3
3. Clay, gray, slightly sandy, unctuous, with considerable manganiferous scale	3
2. Clay, gray, hard and brittle, somewhat sandy, unctuous, with considerable manganiferous scale	3
1. Sand, gray, clayey, fine-grained.	

Bleach ratings of samples from beds 2 and 3 are given below.

Sample	Raw				Acid-treated			
	G	Y	R	B	G	Y	R	B
Bed 3, 1 foot from top	1.1	1.4	1.5	1.6	0.5	0.7	0.9	1.1
Bed 2:								
1 foot from top	.8	1.0	1.1	1.2	.6	.8	1.0	1.2
2 feet from top	.8	1.1	1.2	1.3	.7	.9	1.0	1.1

The upper 3 feet of this clay section appears to be high in bleaching properties, but the remainder of the bed is inferior.

Thin beds of inferior naturally active clay were found on the Denkins, Vickers, and Crane properties west of Tired Creek. These occurrences are probably of no commercial interest.

A 10-foot bed of clay that approaches a commercial grade of activable clay crops out in a ditch 2.4 miles west of Cairo on the old Whigam road. This clay is mottled tan and gray and is very unctuous and somewhat plastic. The middle part of the exposed section is sandy. Bleach ratings of samples from this bed, given below, show the material to be of the activable type of bleaching clay, although the quality is slightly inferior to the commercial grade.

Sample	Raw				Acid-treated			
	G	Y	R	B	G	Y	R	B
Top	0.7	0.8	0.8	0.8	1.3	2.0	2.2	2.3
Middle	.6	.7	.7	.7	1.1	1.4	1.6	1.7
Base	.5	.6	.6	.6	1.4	2.3	2.3	2.3

Little Tired Creek area.—A prospect hole on the property of Miss Pearl Joiner, in the valley of Little Tired Creek at Pelham Mill, 1.7 miles southeast of Cairo, penetrated a thick section of fuller's earth. A single hole was bored on this farm and this revealed the following section:

	Ft.	*in.*
7. Clay, gray, plastic, sandy	4	2
6. Fuller's earth, light gray, slightly sandy, plastic	3	0
5. Fuller's earth, light gray, hard and brittle, unctuous, somewhat sandy	3	0
4. Same with a few very thin sandy streaks	1	0
3. Fuller's earth, light gray, hard and brittle, unctuous, slightly sandy	5	0
2. Same, but more sandy	1	6
1. Fuller's earth, indurated, sandy (could not be penetrated with the available boring equipment).		

Bleach ratings of samples from beds 2, 3, 5, and 6 are given below.

Sample	Raw				Acid-treated			
	G	Y	R	B	G	Y	R	B
Bed 6, 2 feet from top	1.1	1.3	1.4	1.4	0.7	0.8	1.0	1.3
Bed 5:								
Top	.8	1.0	1.1	1.2	.6	.8	.9	1.1
2 feet from top	1.0	1.2	1.3	1.4	.6	.8	.9	1.0
Bed 3:								
3 feet from top	1.1	1.2	1.2	1.2	.7	.9	1.0	1.1
5 feet from top	.8	1.0	1.1	1.2	.6	.8	.9	1.0
Bed 2, top	.9	.9	1.0	1.1	.6	.7	.7	.9

This rather thick section of fuller's earth is fairly consistent in bleaching efficiency throughout and is shown to be of commercial quality. The thickness is known to be at least 14 feet. The extent of this occurrence is not known, but it probably stretches for some distance along Little Tired Creek and toward the Atlantic Coast Line, which lies less than 1 mile to the north of Pelham Mill. The thickness of the overlying beds probably increases with the slope of the valley walls, but it is inferred that a sizable portion of the deposit would lie under an overburden of less than 20 feet. The quality, thickness, and accessibility of this clay bed are favorable to commercial exploitation, and further prospecting is recommended for this area.

Calvary area.—A deposit of low-grade fuller's earth lies on the property of T. H. Elkins, 2.7 miles south of Calvary and a few hundred yards north of the State boundary. It is reported that this deposit covers an area of about 60 acres and that it lies under an overburden that averages from 16 to 18 feet in thickness. The clay bed reaches a maximum thickness of about 8 feet. An auger hole bored on this property revealed the following section:

	Ft.	*in.*
7. Sand, gray and brown clayey	3	0
6. Clay, tan, plastic, sandy	2	6
5. Clay, gray to blue, plastic, sandy, resembling fuller's earth	2	6
4. Fuller's earth, pale bluish green, unctuous, hard and brittle, slightly sandy; thin plastic streaks toward the top	5	0
3. Same but light gray to tan	1	6
2. Fuller's earth, light gray, hard and brittle, sandy	3	6
1. Greenish gray clayey sand.		

Samples from beds 2, 3, 4, and 5 were tested with the following results:

Sample	Raw				Acid-treated			
	G	Y	R	B	G	Y	R	B
Bed 5, 1 foot from top	0.6	0.7	0.7	0.7	1.0	1.6	1.8	1.9
Bed 4, 2 feet from top	.9	1.2	1.3	1.3	.7	.8	.9	1.2
Bed 3, 1 foot from top	.8	1.0	1.1	1.2	.6	.8	.9	1.2
Bed 2:								
1 foot from top	.8	1.1	1.1	1.1	.6	.8	1.0	1.3
3 feet from top	.9	1.1	1.1	1.1	.7	.8	.9	1.3

The gray plastic clay (bed 5) is of the activable type and is fairly active after partial acid leaching. The underlying clay is of the naturally active type and constitutes a low-grade commercial fuller's earth. There is little variation in the bleaching quality of the clay throughout the bed. This location is some 5 miles from the nearest railroad and is not readily accessible. This deposit is not thought to be of particular commercial interest.

THOMAS COUNTY

The fuller's earth zone of the Hawthorn formation crops out in north-central Thomas County and is particularly well developed in the vicinity of Ochlockonee. This zone has been reported[68] at a depth of 100 feet in a well drilled at Thomasville, in the west-central part of the county. Any exposures of fuller's earth in the central and southern parts of the county are to be expected only in the deeper stream valleys.

Investigations in Thomas County were confined to the Ochlockonee area, where rather extensive deposits of commercial grade clay are found. Laboratory tests show this material to compare favorably in bleaching properties with the fuller's earth that is being utilized from this formation elsewhere in the State. Under present economic conditions these deposits constitute valuable reserves and, if the beds that are being worked at the present time should become exhausted or the market should be expanded, this area would be in line for commercial activity.

An auger hole on the property of R. H. Chason, 3.2 miles west of Ochlockonee on the Cairo road, penetrated the following section:

	Feet
4. Sand, gray, clayey, medium-grained	3
3. Clay, gray, plastic, somewhat sandy, similar to fuller's earth in appearance; lower 3 feet interbedded with thin, hard, brittle layers	7
2. Fuller's earth, light gray, unctuous, hard and brittle, somewhat sandy, characterized by much manganiferous scale	18
1. Fuller's earth, gray, very sandy.	

Bleach ratings of samples from beds 2 and 3 are given below:

Sample	Raw				Acid-treated			
	G	Y	R	B	G	Y	R	B
Bed 3:								
Top	0.5	0.6	0.6	0.6	1.1	1.9	2.0	2.1
4 feet from top	.5	.6	.6	.6	1.1	1.9	2.1	2.2
Bed 2:								
Top	.9	1.1	1.2	1.2	.7	1.0	1.1	1.2
3 feet from top	.8	1.2	1.2	1.3	.7	.9	1.0	1.3
6 feet from top	1.1	1.3	1.4	1.4	.6	.7	.8	1.1
9 feet from top	1.1	1.3	1.4	1.5	.7	.9	1.0	1.1
12 feet from top	1.0	1.2	1.4	1.5	.6	.7	.8	.9
15 feet from top	1.1	1.5	1.6	1.6	.6	.7	.8	.9
18 feet from top	1.1	1.3	1.4	1.5	.6	.7	.8	.9

The upper plastic bed of clay (bed 3) differs from the underlying nonplastic clay in that it is very low in bleaching power in the natural state but is distinctly improved by partial acid leaching, whereas the clay of bed 2 is distinctly active in the natural state and the bleaching power remains unchanged or is reduced by acid leaching. Bed 3

[68] Shearer, H. K., op. cit., p. 280.

behaves like the bentonitic clays in its response to acid treatment. The bleaching power of this activated material compares favorably with that of the Ordovician bentonites of northwestern Georgia. The thick fuller's earth bed (bed 2) is shown to be of good commercial quality.

Clay of similar quality is known to occur on the farm of J. F. Singletary, which adjoins the Chason property on the east. The fuller's earth on these properties lies under an overburden which reaches a maximum thickness of about 60 feet, and much of the deposit is less deeply covered. The overburden is slight in the valley of Barnett Creek, which traverses the two properties. The nearest railroad facilities are at Ochlockonee, at a distance of about 3 miles, which may be reached by an all-weather wagon road.

A large prospect pit has been opened at Barrett's mill on Horse Creek, 1.6 miles west of Ochlockonee on the Cairo road. Several carloads of fuller's earth were removed from this pit for testing. The following section was measured in the excavation wall and an auger hole at its base:

	Feet
7. Clay, gray, plastic, sandy	7
6. Fuller's earth, gray, unctuous, hard and brittle, somewhat sandy, laminated	3
5. Fuller's earth, gray, very sandy with some interlaminated sand	3
4. Fuller's earth, gray, unctuous, hard and brittle, slightly sandy, thick-bedded, with occasional thin sand streaks	10
3. Like bed 4 but dark bluish gray and very hard	3
2. Fuller's earth, bluish-gray, very sandy	1
1. Sand, dark gray, slightly clayey, medium-to-fine grained.	

The following bleach ratings were derived from samples taken at various intervals from beds 2, 3, 4, 5, and 6:

Sample	Raw				Acid-treated			
	G	Y	R	B	G	Y	R	B
Bed 6, 3 feet from top	0.9	1.1	1.2	1.3	0.7	0.9	1.0	1.1
Bed 5, 2 feet from top	1.0	1.2	1.3	1.4	.7	.9	1.0	1.1
Bed 4:								
3 feet from top	.9	1.2	1.3	1.4	.7	.9	1.0	1.1
6 feet from top	.9	1.2	1.3	1.4	.6	.8	.8	1.0
9 feet from top	.9	1.1	1.2	1.3	.6	.8	.9	1.1
Bed 3, 1 foot from top	1.0	1.3	1.5	1.6	.6	.8	.9	1.0
Bed 2, top	1.1	1.4	1.5	1.6	.6	.8	.9	1.0

In spite of the varying percentage of admixed sand, the bleach tests show this entire clay section to be fairly uniform in bleaching qualities. This bed is thus a good grade of fuller's earth and sufficiently active to be of commercial interest. A considerable portion of this deposit is covered by an overburden that will not exceed 15 feet. The nearest railroad is at Ochlockonee, about 1.6 miles away.

An exposure in a road cut on United States Highway 19, just south of the Ochlockonee River and 5.2 miles south of Ochlockonee, reveals 5 feet of mottled gray and brown plastic sandy clay which becomes fairly active upon acid treatment. However, it is not sufficiently activable to be of commercial interest as a bleaching clay for oils.

A 9-foot bed of fuller's earth was encountered in a bore hole put down on the property of J. H. Laws, 4.3 miles northeast of Ochlockonee on the old Albany stage road, just south of Oakey Woods Creek. The stratum at this location consists of light-gray hard, brittle, unctuous, more or less sandy clay that may be classified as fuller's earth. The quality of the clay is indicated by the following bleach ratings:

Sample	Raw				Acid-treated			
	G	Y	R	B	G	Y	R	B
Top	0.9	1.2	1.3	1.4	0.7	0.9	1.0	1.2
Middle	1.0	1.2	1.3	1.6	1.0	1.2	1.3	1.6
Base	1.1	1.4	1.6	1.7	.8	1.0	1.2	1.3

The extent of this deposit is unknown, but the quality of the clay is sufficiently good to warrant additional prospecting.

The following section was encountered in a bore hole on the property of James A. Bowers, Jr., 6.4 miles northeast of Ochlockonee on the old Albany stage road:

	Ft.	*in.*
4. Clay, mottled red and gray, plastic	1	0
3. Fuller's earth, gray, unctuous, hard and brittle, somewhat sandy	6	6
2. Conglomerate, consisting of rounded pebbles of fuller's earth in a matrix of clayey medium-grained sand; pebbles become more angular toward base	2	0
1. Fuller's earth interbedded with medium-grained sand	6	0

Samples tested from beds 1 and 3 yielded the following bleach ratings:

Sample	Raw				Acid-treated			
	G	Y	R	B	G	Y	R	B
Bed 3:								
Top	0.8	1.1	1.2	1.3	0.8	1.1	1.3	1.4
3 feet from top	.9	1.1	1.2	1.3	.7	1.0	1.2	1.3
6 feet from top	1.0	1.2	1.3	1.4	.7	1.0	1.2	1.3
Bed 2, 3 feet from top	1.1	1.3	1.3	1.3	.7	1.0	1.1	1.3

The fuller's earth in this section is consistent in bleaching power throughout and is shown to be of commercial quality. The extent of the fuller's earth bed on this property is unknown, but it is thought to cover a considerable area and it is probably covered by a relatively thin overburden of sand and clay. The nearest railroad facilities are at Ochlockonee, at a distance of 6.4 miles, which may be reached by an all-weather wagon road.

Bleaching clays of both the naturally active and activable types were found in auger holes bored on the property of Don Beverly, 1½ miles south of Ochlockonee on the Barnett Creek road. One hole revealed a 6-foot bed of greenish-gray plastic, somewhat sandy clay that was shown by a bleaching test to approach the commercial qualifications of activable clay. This is the most highly activable material found in the Hawthorn formation in Georgia. The bleach rating of this bentonitic (?) material is given below.

Raw				Acid-treated			
G	Y	R	B	G	Y	R	B
0.7	0.8	0.8	0.8	1.2	2.0	2.3	2.6

About one-eighth of a mile east of the locality described above a 5-foot bed of naturally active clay was penetrated in a bore hole. This material is bluish green, very hard and brittle, unctuous, and slightly sandy. The bleach rating of a sample taken from the middle of this bed is as follows:

Raw				Acid-treated			
G	Y	R	B	G	Y	R	B
1.0	1.2	1.3	1.4	0.7	0.9	1.1	1.2

The bleach rating indicates that the clay at this locality is a commercial grade of naturally active clay. It is unlike that described above in that it is an efficient bleaching agent in the natural state but is not improved by acid leaching.

Fuller's earth was encountered in a dug well on the D. E. Fain farm, which adjoins the Beverly property on the south. It is reported that the fuller's earth reaches a thickness of 18 feet at this locality. A sample of clay selected from this well yielded the following bleach rating:

Raw				Acid-treated			
G	Y	R	B	G	Y	R	B
0.7	0.8	0.9	1.0	0.6	0.7	0.8	1.0

This particular sample does not reach the commercial requirements for naturally active clays. The clay is not affected by acid treatment.

SUMMARY AND CONCLUSIONS

Bleaching clays were found in five geologic formations in Georgia. From oldest to youngest these are the Chickamauga limestone (Ordovician), the Midway formation (Eocene), the Barnwell formation (Eocene), the Flint River formation (Oligocene), and the Hawthorn formation (Miocene). Both naturally active and activable clays are represented.

The bentonitic clay in the Chickamauga limestone in Chattooga, Dade, and Walker Counties was found to be of the activable type. Owing to inferior bleaching quality and to the mining difficulties presented by the nature of occurrence, clay from this formation is not thought to be commercially useful as a bleaching agent for oil.

The naturally active clay in the Midway formation of Stewart County is not sufficiently active to compete with present-day commercial clays.

Extensive beds of clay occur in the Twiggs clay member of the Barnwell formation in Crawford, Houston, Jones, Twiggs, Washington, and Wilkinson Counties. Fuller's earth is produced from beds at this horizon in Twiggs and Wilkinson Counties. This bleaching clay is activable as well as naturally active. Throughout most of the formation the material is not sufficiently activable to warrant acid treatment, but in the Irwinton area in Wilkinson County beds are found that meet the requirements of commercial activable clays.

Bentonitic clays occur in the Flint River formation in Crisp, Dougherty, Dooly, Macon, and Sumter Counties, and it is likely that they will be found elsewhere in the area of the outcropping beds in southwestern Georgia. All exposures examined at this horizon proved to be of the activable type of bleaching clay, and certain beds closely approach commercial requirements. It is probable that detailed prospecting will reveal additional deposits which may present commercial possibilities.

The fuller's earth beds in the Hawthorn formation of southwestern Georgia support the most extensive bleaching-clay operations within the State. At the present time deposits in Decatur County contribute an appreciable part of the total world production of fuller's earth. Large deposits of commercial-grade naturally active clay occur in north-central Thomas County and to a lesser extent in Grady County. These deposits constitute valuable reserves and, should the beds now being mined become depleted or should the market be expanded, those in Thomas and Grady Counties would be suitable for commercial development.

FURTHER NOTES ON GEORGIA BLEACHING CLAYS

By A. C. Munyan

All localities from which samples were obtained are listed in the accompanying tables along with the oil-bleach rating for each sample. Consequently, for brevity, no discussion will be given of those samples which do not attain the minimum requirements of commercial bleaching clays. However, all locations, regardless of the rating of the clay samples, are indicated on the accompanying map (pl. 7).

The tables are so arranged that the field stations and samples are listed in sequence under the headings Cretaceous, Eocene, Oligocene, and Miocene. The symbols used in the table are explained on pages 14 and 15.

EOCENE CLAYS

The Twiggs clay member of the Barnwell formation has been described on pages 263–275. The section at station 16, described below, is the only one studied in this formation.

At station 16, in Wilkinson County, 16.2 miles northwest of the courthouse in Dublin, the following section is exposed in a road cut:

	Feet
3. Sand, dark red, coarse-grained	20
Top of auger hole.	
2. Clay, light gray, very waxy and greasy, not gritty	8
1. Sand, gray, medium-grained	(?)

Three samples were tested from this locality and found to have fairly high bleaching properties after acid treatment. The bed should be examined further to determine its economic value.

OLIGOCENE CLAYS

The name "Flint River formation" has recently been proposed by Cooke [69] for the deposits in Georgia and adjacent States which he had formerly correlated with the Glendon limestone of western Alabama but which now seem to be somewhat younger. They include parts of deposits described as Vicksburg and Chattahoochee formations in earlier reports. The formation is described on pages 275–278.

Two sections were studied in the Flint River formation, as shown below, station 30 in Sumter County and station 42 in Dooly County.

The following section appears at station 30, in a cut on Georgia Highway 28, 3 miles east of the Americus post office, Sumter County:

	Ft.	in.
4. Clay, brown and red, waxy	2	0
3. Clay, gray, mottled brown, waxy		10
2. Clay, gray, streaked red, waxy; small sand laminae	3	2
1. Sand, red, coarse-grained	(?)	

Two samples from different layers in the clay bed gave a bleach rating after acid treatment well above the minimum requirement for commercial use.

[69] Cooke, C. W., Am. Assoc. Petroleum Geologists Bull., vol. 19, p. 1170, August 1935.

At station 42 in Dooly County, 4.6 miles northwest of the Atlanta, Birmingham & Coast Railroad crossing in Vienna, on Georgia Highway 90, the following section was measured:

	Ft.	in.
5. Soil, brown, argillaceous	1	0
4. Clay, gray, waxy, gritty; considerable tan chert	3	0
Top of auger hole.		
3. Clay, green, mottled red, waxy, sandy; small chert fragments	6	0
2. Clay, red, streaked green, waxy, sandy, some chert		6
1. Sand and chert, tan and gray	(?)	

Four samples were taken at this locality. As shown in the tables the bleach ratings indicate a good activable clay. Although the beds are somewhat sandy and cherty, the deposit is worthy of further investigation.

MIOCENE CLAYS

The deposits in Georgia that were called "Alum Bluff formation" in earlier reports have been found to be the continuation of the Hawthorn formation of Florida. In both States the Hawthorn formation contains notable deposits of fuller's earth, but the greater part of the Hawthorn is composed of sand of various degrees of fineness.

The Hawthorn formation has been described on pages 278–289. Six sections of the formation were studied as follows: Station 51, in Decatur County; stations 59, 60, and 67, in Grady County; station 71, in Brooks County; and station 73, in Colquitt County.

The present operating mine of the Attapulgus Clay Co. (station 51), southwest of Attapulgus, Ga., in Decatur County, shows the following section:

	Feet
4. Sand and soil, gray and brown	6
3. Clay; gray, waxy, sandy, somewhat plastic	3
2. Sand, gray, medium-grained, cross-bedded, clayey	12
1. Fuller's earth bed (now being mined)	9

A sample was taken from the 3-foot clay bed 12 feet above the fuller's earth. The bleach rating indicates an activable clay with an exceptional red separation. This clay is now stripped off as overburden in the mining of the fuller's earth below. Perhaps some use can be made of it in the future.

The following section is exposed at station 59, on United States Highway 84, 7 miles west of the courthouse in Thomasville:

	Feet
4. Sand, gray, fine-grained, loosely consolidated	3
3. Sand, gray and tan, mottled red, coarse-grained, compact	6
2. Clay, gray, mottled brown and red, waxy, sandy, much manganese stain	4
1. Sand, gray and tan, coarse-grained	1

Of two samples tested from this exposure, the upper one fell within the commercial range; the lower one did not. In order to gain more knowledge of the bed's extent, an auger hole was drilled 550 feet north of the exposure. The top of the hole was approximately level with the top of the clay bed, but after boring to a total depth of 12 feet without encountering clay the hole was abandoned. No other test holes were placed in the vicinity because of the lack of time.

At another outcrop on United States Highway 84, at station 60, 2.7 miles west of station 59, 4 feet of gray, mottled brown waxy, sandy clay was exposed. The auger penetrated an additional 2 feet of the same clay. Three samples obtained show a bleach rating very close to the minimum. However, the bed seems to be worth further prospecting.

At station 67, in Grady County, 1.4 miles northeast of the Florida boundary, on the Beachton-Meridian (Fla.) road, the following section was measured:

	Feet
2. Sand, reddish brown, coarse-grained	4
1. Clay, gray, mottled brown, waxy, sandy	2

A sample from the clay bed gave a very high bleach rating. As the exposure was not drilled the total thickness of the bed at this point is unknown. However, the locality should be explored in more detail by anyone interested in a possible commercial venture.

Station 71 is on the property of C. E. Clanton, in the southeast corner of Brooks County, on the west side of the Withlacoochee River. As there is no natural exposure here, the following section was obtained by means of the hand auger:

	Ft.	*in.*
3. Sand, gray, fine-grained, clayey	13	5
2. Clay, greenish gray, very waxy, very plastic, puttylike consistency	8	4
1. Limestone, white, siliceous, pitted with solution cavities	(?)	

Four samples from the clay bed indicate a deposit of activable clay of exceptionally good quality. The deposit deserves the attention of commercial operators in order to determine its extent and quality at other points. A strong recommendation can be made for this work.

At station 73, in Colquitt County, on Georgia Highway 37, 9.6 miles west of the courthouse in Moultrie, this section was measured:

	Ft.	*in.*
7. Sand, gray, coarse-grained, cross-bedded	9	0
6. Clay, gray, mottled brown, waxy, sandy	2	0
Top of auger hole.		
5. Clay, gray and brown, waxy, sandy	3	0
4. Sand and clay, gray and brown, interbedded in 4-inch layers	1	0
3. Clay, gray and brown, waxy, sandy, some manganese stain	2	0
2. Sand, gray, medium-grained, considerable manganese stain, argillaceous		6
1. Clay, greenish gray, waxy, sandy, manganese stain		3

Samples obtained from this deposit gave a bleach rating sufficiently high to meet commercial requirements. The bed should be further explored because of its good quality.

Bleach ratings of clay samples from Georgia

Cretaceous clays, Ripley formation

Station No.	Location	Description of bed: Character	Thickness	Position of sample in bed	Bleach rating: Raw G	Raw Y	Raw R	Raw B	Acid-treated G	Acid-treated Y	Acid-treated R	Acid-treated B	Acid-soluble Fe	Al	Ca	Off (percent)
			Ft. in.													
1	Muscogee County; Georgia Highway 103, 1 mile east of Central of Georgia R. R., at east edge of Columbus.	Greenish gray, mottled brown and red, laminated, waxy, sandy, lenticular.	3 0	Composite	0.2	0.3	0.3	0.3	0.9	1.5	1.8	2.2	5	5	Tr.	30
2	Marion County; Georgia Highway 103, 4.5 miles east of Chattahoochee County line.	Tan, massive, dull luster, not gritty	1 0	do	.6	.7	.7	.7	.6	.7	.8	.8	9	1	0	20

Eocene clays, Midway formation

Station No.	Location	Description of bed: Character	Thickness	Position of sample in bed	Bleach rating: Raw G	Raw Y	Raw R	Raw B	Acid-treated G	Acid-treated Y	Acid-treated R	Acid-treated B	Acid-soluble Fe	Al	Ca	Off (percent)
3	Stewart County; 2 miles west of Trotman on county road.	White, stained pink, bedded, chalky, conchoidal fracture.	20 0	Basal 1 foot	0.5	0.6	0.6	0.6	0.8	1.0	1.1	1.3	0	10	0	10
4	Stewart County; U. S. Highway 280, 1.2 miles northwest of Richland.	Yellowish tan, waxy, gritty	[1]	Composite	.6	.8	.9	1.0	.7	.8	.8	.9	7	3	0	25
5	Webster County; U. S. Highway 280, 5.6 miles west of Preston.	Grayish white, mottled red, waxy, gritty	3 0	do	.5	.6	.6	.6	.5	.6	.6	.6	6	4	0	15
6	Webster County; U. S. Highway 280, 3.4 miles west of Preston.	Mottled tan and red, waxy, gritty	2 6	do	.6	.8	.9	.9	.7	.8	.9	1.1	7	3	0	25
7	Webster County; U. S. Highway 280, 15.3 miles west of U. S. Highway 19 at Americus.	Gray, mottled red, waxy, sandy	6 0	Top 1 foot	.4	.5	.5	.5	1.3	1.5	1.5	1.5	5	4	1	25
				Middle 1 foot	.6	.7	.8	1.0	.5	.8	1.0	1.2	7	2	1	15
				Basal 1 foot	.1	.2	.2	.2	1.1	1.7	2.0	2.2	5	4	1	30
8	Webster County; U. S. Highway 280, 14.1 miles west of U. S. Highway 19 at Americus.	Grayish white, mottled red, waxy, sandy	4 0	Composite	.5	6.	.7	.7	.6	.8	1.0	1.2	5	5	0	20
9	Macon County; Georgia Highway 26, 5.7 miles east of Montezuma Square.	Gray, streaked red, a little waxy, sandy	4 0	do	.8	1.0	1.1	1.2	.9	1.2	1.4	1.7	5	5	Tr.	25

[1] Slumped.

Bleach ratings of clay samples from Georgia—Continued

Eocene clays, Claiborne group

Station No.	Location	Description of bed: Character	Thickness (Ft. in.)	Position of sample in bed	Raw G	Raw Y	Raw R	Raw B	Acid-treated G	Acid-treated Y	Acid-treated R	Acid-treated B	Acid-soluble Fe	Al	Ca	Off (percent)
10	Randolph County; 4.3 miles south of Cuthbert Square on Carnegie Road.	Interbedded clay and sand; clay is gray, mottled red, waxy and sandy.	4 0	Composite	.9	1.1	1.1	1.2	1.1	1.5	1.7	2.0	5	5	0	30
11	Sumter County; U. S. Highway 280, 2.4 miles west of U. S. Highway 19 at Americus, 1.0 mile north to edge of McMath's mill pond.	Gray and yellow, laminated, waxy, gritty.	2 0	Top 6 inches	.6	.7	.7	.7	1.3	1.9	2.1	2.4	5	4	1	30
			2 0	Basal 6 inches	.6	.7	.7	.8	1.2	1.8	2.0	2.3	5	4	1	25

Eocene clays, Twiggs clay member of Barnwell formation

Station No.	Location	Description of bed: Character	Thickness (Ft. in.)	Position of sample in bed	Raw G	Raw Y	Raw R	Raw B	Acid-treated G	Acid-treated Y	Acid-treated R	Acid-treated B	Acid-soluble Fe	Al	Ca	Off (percent)
13	Twiggs County; Georgia Highway 57, 16 miles west of Irwinton.	Greenish gray, waxy, not gritty, some manganese.	10 0	Basal 1 foot	0.9	1.1	1.2	1.4	0.8	1.0	1.1	1.3	5	5	Tr.	25
14	Wilkinson County; Irwinton, north edge of town limit, 900 feet east down hill to gully.	Light gray; bedded, somewhat waxy, not gritty, some manganese, very blocky.	10 0	Top 1 got	1.0	1.2	1.3	1.5	.8	1.0	1.1	1.3	5	5	Tr.	20
				Middle 1 foot	.8	1.0	1.2	1.3	.6	.9	1.1	1.2	5	5	Tr.	20
				Basal 1 foot	1.1	1.3	1.4	1.5	1.0	1.4	1.6	1.7	5	5	Tr.	20
15	Wilkinson County; Georgia Highway 29, 17.1 miles northwest of courthouse in Dublin.	Greenish gray, streaked yellow, evenly bedded, a little waxy, siliceous nodules; some manganese.	30 0	Middle 1 foot	1.1	1.3	1.4	1.5	.9	1.4	1.6	1.7	5	4	1	15
16	Wilkinson County; 0.9 mile southeast of station 15; same road; auger sample.	Light gray, laminated, very waxy and greasy; no grit.	8 0	1 foot below top	.2	.3	.3	.3	1.2	1.3	1.4	1.5	5	4	1	25
				4 feet below top	.7	.8	.9	.9	1.5	2.2	2.6	2.9	5	4	1	25
				6 feet below top	6	7	.8	.8	1.4	1.9	2.2	2.7	5	4	1	25
17	Laurens County; Georgia Highway 29, 12.2 miles northwest of courthouse in Dublin; auger sample.	Gray, waxy, sandy, yellowish tan, flat luster, gritty.	1 0	Composite	.2	.3	.3	.3	1.2	1.8	1.9	1.9	4	6	0	25
			1 0	do	.3	.4	.4	.4	1.5	2.1	2.2	2.2	4	6	0	30

Oligocene clays

18	Randolph County; Carnegie Road, 5 miles south of Cuthbert Square, then 0.5 mile west on private road; gully of Carter Creek.	Gray, mottled brown and red, waxy, sandy	4	0	Composite	0.5	0.6	0.7	0.7	1.3	1.9	2.1	2.2	5	5	Tr.	25
19	Randolph County; 2 miles southeast of Cuthbert on Central of Georgia R. R. to county road, then 0.7 mile south to road cut.	Brown, streaked gray, waxy, sandy	3	0	do	.8	1.0	1.1	1.2	1.1	1.6	1.8	2.1	6	4	0	30
20	Randolph County; Central of Georgia R. R., 2.2 miles southeast of Cuthbert, 300 feet north to road cut; auger samples except top 3 feet.	Brown and gray mottled, waxy, sandy	14	6	Top 3 feet	.9	1.0	1.0	1.1	1.0	1.3	1.5	1.6	6	4	0	25
					4 feet below top	.6	.7	.8	.9	1.1	1.3	1.4	1.6	6	4	0	25
					7 feet below top	.6	.7	.8	.9	1.1	1.4	1.6	1.9	5	5	0	25
					9.7 feet below top	.6	.7	.8	.9	.8	1.0	1.1	1.3	5	5	0	25
					12.2 feet below top	.6	.7	.8	.9	.7	1.0	1.3	1.7	5	5	0	25
21	Randolph County; same county road as No. 20, 2.3 miles southeast of No. 20.	Gray, mottled brown, waxy, sandy	4	0	Composite	.7	.8	.9	.9	.7	1.0	1.2	1.5	6	4	0	25
22	Terrell County; Georgia Highway 50, 0.9 mile west of Dawson main street.	Gray, mottled red, waxy, sandy	2	0	do	1.0	1.1	1.2	1.3	.8	1.1	1.2	1.4	6	4	0	25
23	Sumter County; 1.9 miles north of Plains on county road.	Brown, mottled red, waxy, gritty	4	0	do	.7	.8	.8	.9	1.2	1.7	2.0	2.4	5	5	0	25
24	Sumter County; 2.5 miles north of Plains on county road.	Gray and tan, mottled red and brown, waxy, gritty.	5	0	do	.7	.8	.8	.8	1.1	1.4	1.6	1.9	6	4	0	30
25	Sumter County; Concord Church road, 7.5 miles northwest of Americus city limit.	Brown, streaked gray, waxy, gritty	4	0	do	.7	.8	.9	1.0	.9	1.2	1.4	1.8	5	5	0	30
26	Sumter County; U. S. Highway 280, 2.4 miles west of U. S. Highway 19 at Americus, 900 feet north along county road to cut; auger samples except top 3 feet.	Reddish brown, waxy, sandy. At 7.8 feet below top gray, mottled brown, waxy, sand laminae; much manganese. At 11.8 feet below top red, spotted gray, waxy, sandy.	11	10	Top 3 feet	.8	.9	1.0	1.0	1.0	1.2	1.4	1.8	5	5	0	25
					7 feet below top	.3	.4	.4	.4	.9	1.3	1.6	1.7	5	5	0	25
					7.8 feet below top	.6	.7	.7	.8	1.0	1.5	1.8	2.4	4	6	0	25
					11.8 feet below top	.8	1.0	1.1	1.3	1.1	1.5	1.7	2.0	6	4	0	30
27	Sumter County; U. S. Highway 19, 1.1 miles south of Central of Georgia R. R. crossing in Americus.	Gray and yellow, laminated, waxy, sandy, plastic.	5	0	Top 6 inches	.5	.6	.6	.7	.5	.6	.7	.7	5	5	0	20
					Middle 1 foot	.5	.6	.6	.7	.6	.8	.9	1.0	5	5	0	20
					Basal 6 inches	.4	.5	.5	.5	.6	.7	.7	.8	5	5	0	20
28A	Sumter County; U. S. Highway 19, 1.6 miles south of Central of Georgia R. R. crossing in Americus; property of W. R. Hansford.	Light gray and brown, sandy, badly weathered.	2	0	Composite	.5	.6	.6	.6	1.2	1.5	1.7	2.0	5	5	Tr.	25
28B	Auger hole 50 feet south of outcrop at 28A	Gray, waxy, a little gritty, plastic. At 3 feet below top gray, mottled pink, waxy, gritty, plastic. At 4 feet gray, waxy, sandy, very plastic. At 6 feet pink, waxy, gritty.	6	0	Top 1 foot	.3	.4	.4	.4	.9	1.2	1.4	1.6	5	5	0	25
					3 feet below top	.5	.6	.6	.6	.8	1.0	1.3	1.5	5	5	0	20
					4 feet below top	.7	.8	.9	1.0	.8	1.0	1.2	1.4	5	5	0	25
					6 feet below top	.3	.4	.4	.4	1.1	1.3	1.4	1.5	5	5	Tr.	20

Bleach ratings of clay samples from Georgia—Continued

Oligocene clays—Continued

Station No.	Location	Description of bed			Position of sample in bed	Bleach rating								Acid-soluble			
		Character	Thickness			Raw				Acid-treated				Fe	Al	Ca	*Oil* (per-cent)
			Ft.	*in.*		G	Y	R	B	G	Y	R	B				
29	Sumter County; Georgia Highway 28; 1.7 miles east of Americus post office.	Brown and white mottled, waxy, somewhat sandy.	1	0	Composite	1.1	1.3	1.4	1.4	1.3	1.6	1.8	2.0	5	5	0	25
30	Sumter County; Georgia Highway 28, 1.3 miles east of station 29; auger samples.	Gray, mottled brown, waxy, sandy. At 3 feet gray, streaked red, waxy; sand laminae at base.	6	0	2.6 feet below top	1.1	1.3	1.4	1.6	1.3	2.0	2.4	2.5	6	4	0	25
					3 feet below top	.8	.9	.9	1.0	1.3	2.2	2.8	3.6	5	5	Tr.	30
					5.7 feet below top	.7	.8	.8	.8	1.2	1.8	2.1	3.1	5	5	Tr.	25
31	Sumter County; Georgia Highway 28, 2.9 miles east of station 30.	Light gray, mottled brown and red, greasy, sandy.	3	6	Composite	.8	1.1	1.2	1.4	1.3	1.5	1.6	1.9	5	5	Tr.	30
33	Sumter County; U. S. Highway 280, 12.1 miles southeast of Americus post office; auger samples.	Gray, mottled red and brown, waxy, sandy	5	0	4 feet below top	1.0	1.2	1.3	1.4	.9	1.3	1.6	2.1	5	5	Tr.	25
34	Decatur County; west bank of Flint River, 6 miles north of Atlantic Coast Line at Bainbridge.	Gray, greasy, gritty, very irregularly bedded. Below 1 foot gray, waxy, sandy, in small lenses.	1	0	Composite	.7	.9	1.0	1.1	.7	1.1	1.3	1.5	4	5	1	20
			1	0	do	.9	1.1	1.2	1.4	.9	1.3	1.5	2.0	5	5	Tr.	25
35	Decatur County; U. S. Highway 27, 4.1 miles south of southeastern city limit of Bainbridge.	Greenish gray, mottled red, sandy, gummy,	3	0	do	.6	.7	.7	.7	.9	1.5	1.9	2.7	5	4	1	30
36	Worth County; about 2 miles northeast of Acree.	Brown, mottled red, waxy, sandy; some chert particles.	2	0	do	1.0	1.1	1.2	1.2	1.0	1.4	1.6	1.9	6	4	0	25
37	Worth County; Warwick Road, 8 miles north of Sylvester.	Gray, mottled red, waxy, sand streaks			do	.8	.9	.9	.9	1.1	2.0	2.1	3.0	4	6	Tr.	25
38	Worth County; Warwick Road, 2 miles north of station 37; auger samples.	Brown and yellow mottled, waxy, sandy	3	3	Top 1 foot	1.2	1.4	1.5	1.6	1.1	1.8	2.0	2.4	5	5	0	25
					2.8 feet below top	.9	1.1	1.2	1.3	1.1	1.3	1.5	2.2	5	5	0	30
39	Worth County; Georgia Highway 33, 16.5 miles south of courthouse in Cordele.	Light gray, mottled brown, waxy, sandy	5	0	Composite	1.0	1.1	1.1	1.1	.8	1.3	1.5	2.2	5	5	Tr.	25
40	Worth County; Georgia Highway 33, 13.4 miles south of courthouse in Cordele; auger samples except top 3 feet.	Light gray, waxy, sandy. At 4 feet gray, waxy, sandy. At 8 feet 6 inches gray, mottled pink; waxy; sandy.	8	6	Top 3 feet	.4	.5	.5	.5	.7	11	1.3	1.9	5	5	Tr.	25
					4 feet below top	.7	.8	.9	.9	1.0	1.4	1.8	2.4	5	5	0	25
					6.3 feet below top	.5	.6	.6	.6	1.2	1.7	1.9	2.7	5	5	0	25

41	Crisp County; U. S. Highway 41, 5.7 miles south of courthouse in Cordele.	Gray, mottled brown, waxy, sandy	4	0	Composite	.6	.7	.7	.7	.8	1.0	1.2	2.1	5	4	1	25
42	Dooly County; Georgia Highway 90, 4.6 miles northeast of Atlanta, Birmingham & Coast R. R. crossing at Vienna; auger samples except top 3 feet.	Green, mottled red, waxy, sandy; small chert fragments intermixed. Lower 6 inches brownish red, streaked green, waxy, sandy, chert particles.	9	6	Top 3 feet	1.0	1.1	1.2	1.3	1.6	2.1	2.8	3.4	6	3	1	30
					3.6 feet below top	1.2	1.4	1.5	1.5	1.2	1.6	2.0	2.3	6	3	1	30
					6.1 feet below top	.7	.8	.8	.9	1.0	1.7	2.2	2.9	4	5	1	25
					6.4 feet below top	.8	1.1	1.2	1.5	1.1	1.5	1.7	2.0	6	4	Tr.	25
43	Dooly County; Georgia Highway 90, 5.2 miles northwest of station 42; 0.4 mile southeast of Turkey Creek, same location as first described in Dooly County by Bay; auger samples.	Top foot brown, mottled red, waxy, sandy. 2 feet 3 inches gray, mottled red and brown, waxy, sandy. 1 foot 7 inches gray, mottled red, waxy, sandy. 1 foot 3 inches gray and tan mottled, waxy, sandy. 1 foot 7 inches gray and brown, waxy, sandy.	7	8	1 foot below top	.7	.8	.8	.8	1.0	1.3	1.5	1.6	5	5	0	25
					2.4 feet below top	.7	.8	.8	.9	.8	1.0	1.2	1.4	5	5	Tr.	25
					3.3 feet below top	.7	.8	.8	.9	1.0	1.3	1.5	1.6	4	5	1	20
					4.6 feet below top	.7	.8	.8	.8	1.2	1.5	1.7	2.1	4	5	1	25
					6.0 feet below top	.6	.7	.7	.7	1.1	1.6	1.9	2.2	5	4	1	25
					7.6 feet below top	.9	1.1	1.2	1.3	1.1	1.5	1.8	2.6	6	4	Tr.	30
44	Dooly County; Georgia Highway 90, 0.8 mile west of Atlanta Birmingham & Coast R. R. crossing in Byromville.	Gray, mottled brown and red, waxy, gritty.	8	0	Middle foot	.7	.9	1.0	1.1	.9	1.2	1.4	1.8	5	5	0	20
					Basal foot	.8	1.0	1.1	1.2	.7	1.0	1.2	1.3	6	4	0	30
45	Dooly County; Georgia Highway 28, 8.6 miles northeast of Vienna Square; auger samples except top 3 feet. Total thickness of beds sampled 18 feet 2 inches.	Gray, streaked red, irregularly bedded, waxy, gritty.	3	0	Top 1 foot	.8	1.0	1.1	1.2	1.1	1.7	2.1	2.5	5	5	Tr.	30
		Light gray, waxy, not gritty	2	0	1 foot below top	.7	.8	.8	.9	1.1	1.7	2.0	2.4	5	4	1	25
		Gray mottled purple, waxy, not gritty		7	0.2 feet below top	.7	.8	.8	.8	1.2	1.8	2.0	2.1	5	4	1	25
		Light gray, waxy	1	2	Top of bed	.8	.9	.9	.9	1.1	1.6	1.9	2.4	4	5	1	30
		Light gray and yellowish, waxy	4	10	Top of bed	.8	.9	1.0	1.0	.8	1.1	1.6	2.0	4	5	1	30
					3.8 feet below top	.9	1.1	1.1	1.2	.9	1.4	1.9	2.2	4	5	1	30
					Base of bed	.7	.8	.9	1.0	.9	1.4	1.9	2.3	5	4	1	25
		Gray, streaked red, waxy, sandy	3	3	2.6 feet below top	.8	.9	1.0	1.1	.9	1.4	1.7	2.0	5	5	Tr.	20
					Base of bed	.7	.8	.9	1.0	.9	1.5	1.9	2.5	5	4	1	25
		Gray and yellow, waxy, sandy	3	4	Base of bed	.9	1.1	1.2	1.4	.8	1.4	1.6	1.9	5	4	1	30
46	Dooly County; Georgia Highway 28, 14.2 miles northeast of Vienna Square.	Gray, mottled red and brown, waxy, sandy	2	0	Composite	.8	1.0	1.1	1.2	.8	1.2	1.3	1.3	5	5	0	25
47	Houston County; Georgia Highway 26, 4.1 miles east of Southern Ry. at Elko.	Greenish gray, mottled brown, waxy, sandy.	2	0	do	.9	1.0	1.0	1.0	1.3	1.4	1.4	1.4	6	3	1	30
48	Bleckley County; Georgia Highway 26, 6.1 miles northeast of Cochran main street.	Gray, mottled red, waxy, sandy	3	0	do	.9	1.0	1.0	1.1	.9	1.2	1.4	1.7	5	5	0	25
49	Laurens County; Georgia Highway 29, 1.2 miles north of courthouse in Dublin, south bank of Hunger and Hardship Creek.	Yellowish, waxy, sandy	1	0	do	.4	.5	.5	.5	1.2	1.3	1.3	1.3	5	5	0	25
50	Laurens County; Georgia Highway 29, 8.1 miles northwest of courthouse in Dublin.	Gray, mottled red and brown, somewhat waxy, sandy.	3	0	do	1.0	1.1	1.2	1.2	1.1	1.4	1.6	1.8	5	5	0	25

Bleach ratings of clay samples from Georgia—Continued

Miocene clays

Station No.	Location	Description of bed: Character	Thickness: Ft.	Thickness: in.	Position of sample in bed	Bleach rating, Raw: G	Raw: Y	Raw: R	Raw: B	Acid-treated: G	Acid-treated: Y	Acid-treated: R	Acid-treated: B	Acid-soluble: Fe	Al	Ca	Oil (percent)
51	Decatur County; Attapulgus Clay Co., operating mine. See samples by Bay from this locality (p. 274).	Gray, waxy, sandy, plastic. Base of this bed is 3 feet above fuller's earth bed now being mined.	3	0	Composite	0.2	0.3	0.3	0.3	0.8	1.3	1.6	3.2	6	3	1	30
52	Grady County; U. S. Highway 84, 8.1 miles west of courthouse in Cairo.	Gray, mottled brown, waxy, sandy, white siliceous concretions.	7	0	Basal 1 foot	.4	.6	.7	.7	.8	1.1	1.4	1.9	5	4	1	30
53	Grady County; U. S. Highway 84, 2 miles west of courthouse in Cairo, then 1 mile north on county road.	Tannish gray, laminated, somewhat waxy, not gritty.	4	0	Top 1 foot	.6	.7	.8	.9	1.2	1.7	2.1	2.6	5	5	0	30
					Basal 1 foot	.4	.6	.7	.9	.8	1.3	2.1	2.1	5	5	0	30
54	Grady County; Cairo-Pelham road, about 0.5 mile due west of Ochlockonee, property of Mrs. Pope Forester; auger samples except top 6 feet.	Light gray, laminated, waxy, a little gritty	6	0	Top 1 foot	.4	.5	.5	.5	1.0	1.2	1.3	1.6	5	5	Tr.	30
					2 feet below top	.2	.3	.3	.4	1.0	1.2	1.4	1.6	4	5	1	25
		Greenish gray, waxy, not gritty	3	0	Top of bed	.4	.5	.5	0.5	1.3	1.8	1.9	1.9	5	4	1	25
					2 feet below top	.5	.6	.7	.9	.6	.7	.8	.9	5	4	1	25
55	Grady County; old Pelham road, 7 miles northeast of Cairo.	Gray, mottled brown, waxy, sandy, a little mica, granular.	5	0	Composite	.7	.9	1.0	1.0	.7	1.1	1.3	1.4	7	3	0	35
56	Thomas County; 1.6 miles west of U. S. Highway 19 in Ochlockonee, on county road at Barrett's mill; auger samples. See samples reported from this locality by Bay (p. 286).	Gray, mottled red, waxy, very little grit	4	6	2 feet below top	.6	.6	.7	.7	.7	1.6	2.2	2.6	6	4	0	30
					4.5 feet below top	.6	.7	.7	.7	1.2	1.9	2.0	2.0	5	5	Tr.	25
		Gray, waxy, gritty; becomes very sandy toward base.	8	2	2.3 feet below top	.5	.6	.6	.6	1.0	1.5	1.8	2.7	5	5	Tr.	25
					4.1 feet below top	.7	.8	.9	1.0	.9	1.4	1.8	2.7	5	5	Tr.	25
					6.5 feet below top	.9	1.1	1.2	1.2	1.0	1.3	1.6	2.4	5	5	Tr.	25
					8.1 feet below top	.6	.7	.7	.7	1.0	1.4	1.7	2.6	5	4	1	25
		Bluish gray, waxy, gritty, thin beds of light-gray clay alternating throughout.	7	0	2.5 feet below top	1.2	1.5	1.7	1.7	.9	1.2	1.7	2.3	5	5	Tr.	25
					4.5 feet below top	1.3	1.6	1.9	2.0	1.0	1.2	1.8	2.4	5	5	Tr.	25
					Base of bed	1.1	1.4	1.6	1.7	.7	1.0	1.1	1.9	5	4	1	25
57	Thomas County; U. S. Highway 19, 5.3 miles south of railroad station in Ochlockonee. See samples reported here by Bay (p. 287).	Greenish gray, laminated, waxy, gritty; some small siliceous nodules; a little manganese.	10	0	Top 1 foot	.3	.4	.4	.4	.9	1.2	1.8	2.6	5	5	0	25
					Middle 1 foot	.8	1.0	1.1	1.1	.7	1.0	1.4	2.3	5	5	Tr.	25
					Basal 1 foot	.3	.3	.3	.3	.8	1.1	1.5	2.6	3	5	2	30
58	Thomas County; U. S. Highway 84, 1.6 miles west of courthouse in Thomasville.	Gray, mottled dark red, waxy, sandy	6	0	Top 1 foot	.8	.9	.9	.9	.9	1.3	1.6	1.9	6	4	0	25
					Middle 1 foot	.8	.9	.9	.9	.7	1.1	1.2	1.6	5	5	0	25
					Basal 1 foot	.7	.8	.9	.9	.9	1.1	1.3	1.5	3	7	0	25

59	Grady County; U. S. Highway 84, 7 miles west of courthouse in Thomasville.	Gray, mottled red and brown, irregularly laminated, waxy, sandy, some manganese.	4	0	Top 1 foot	1.4	1.6	1.7	1.7	1.1	2.5	2.9	2.9	6	3	1	30
					Basal 1 foot	.5	.6	.7	.9	1.1	1.9	2.0	2.0	4	5	1	25
60	Grady County; U. S. Highway 84, 2.7 miles west of station 59; bottom foot auger sample.	Gray, mottled brown, very waxy, sandy	6	0	Top 1 foot	.5	.6	.6	.6	1.0	1.8	2.4	2.9	4	6	0	25
					Middle 1 foot	.5	.6	.6	.6	.9	1.6	2.0	2.4	4	6	0	25
					Basal 1 foot	.3	.4	.5	.6	1.0	1.7	2.1	2.9	5	5	0	25
61	Grady County; 2.6 miles southwest of railroad in Pine Park, on county road; auger samples except 1 foot below top.	Gray, mottled red, waxy, sandy	5	0	1 foot below top	.7	.8	.8	.9	1.2	2.0	2.4	2.6	5	5	Tr.	25
					3 feet below top	.8	.9	1.0	1.1	1.2	1.5	1.9	2.4	5	5	Tr.	25
					5 feet below top	.8	.9	.9	1.0	1.0	1.2	1.7	2.0	5	5	0	25
62	Grady County; 0.6 mile southwest of station 61, same road.	Gray, mottled purple, laminated, waxy and greasy, gritty.	5	0	2 feet below top	.4	.5	.5	.5	1.2	1.7	2.0	2.4	5	5	0	25
					5 feet below top	.8	.9	.9	.9	1.1	1.7	2.1	2.7	5	5	Tr.	25
63	Grady County; Georgia Highway 93, 1.7 miles south of courthouse in Cairo, then 0.5 mile east on county road.	Gray, laminated, waxy, sandy; about 30 to 50 feet above a bed reported by Bay from this locality (p. 283).	3	0	Composite	.4	.5	.5	.5	1.0	1.2	1.3	1.6	5	5	Tr.	30
64	Grady County; Georgia Highway 93, 3.6 miles southeast of courthouse in Cairo, then 1.1 miles west on county road.	Gray, somewhat waxy, very sandy, badly weathered.	3	0	Basal 1 foot	.4	.5	.5	.6	1.1	1.3	1.9	2.6	5	5	0	30
65	Grady County; Georgia Highway 93, 4.5 miles northwest of U. S. Highway 19; auger samples except 1 foot below top.	Light gray, mottled purplish red, very waxy, gritty, plastic.	5	0	1 foot below top	.8	1.0	1.1	1.2	1.1	1.4	1.6	1.9	5	5	Tr.	25
					3 feet below top	.8	1.0	1.1	1.3	1.1	1.4	1.7	2.2	5	5	Tr.	25
					5 feet below top	.7	.9	1.0	1.2	.8	1.2	1.4	1.7	4	6	Tr.	25
66	Grady County; Georgia Highway 93, 0.5 mile southwest of U. S. Highway 19; auger sample at 5 feet below top.	Gray, mottled red, waxy, a little gritty	5	0	Top 1 foot	.8	1.0	1.2	1.4	.8	1.0	1.3	1.5	6	4	0	30
					3 feet below top	.4	.5	.6	.7	.8	1.1	1.3	1.6	6	4	0	25
					5 feet below top	.8	1.0	1.1	1.2	1.0	1.2	1.3	1.9	5	5	0	25
67	Grady County; Meridian (Fla.) road, 1.4 miles northeast of Florida line.	Gray, mottled brown, waxy, sandy	2	0	Middle 1 foot	1.2	1.4	1.5	1.7	1.4	2.1	2.9	3.6	5	5	0	30
68	Grady County; U. S. Highway 19, 14.1 miles south of courthouse in Thomasville; auger samples from lower 3 feet.	Gray, mottled brown, waxy, gritty	8	0	Top 1 foot	.8	1.0	1.1	1.3	1.1	1.5	1.7	1.9	5	5	0	25
					5 feet below top	.2	.3	.3	.3	1.1	1.5	1.7	2.0	5	5	0	30
					6 feet below top	.5	.6	.6	.6	1.1	1.5	1.7	2.1	5	5	0	30
					8 feet below top	.2	.3	.3	.3	1.2	1.6	1.8	1.9	5	5	0	25
69	Thomas County; Georgia Highway 35, 3.9 miles southeast of courthouse in Thomasville.	Light gray, mottled brown, very waxy, gritty.	6	0	Top 1 foot	.7	.8	.9	.9	.9	1.2	1.4	1.7	5	5	0	25
					Middle 1 foot	.3	.4	.4	.4	.9	1.2	1.9	2.9	5	5	0	30
					Basal 1 foot	.2	.3	.3	.3	.6	.9	1.2	2.2	5	5	0	25
70	Thomas County; Georgia Highway 35, 0.6 mile southeast of station 69.	Gray, mottled red, waxy, sandy	4	0	Basal 1 foot	1.1	1.3	1.4	1.6	1.0	1.4	1.6	1.9	4	6	0	30
71	Brooks County, southeast corner, 1 mile north of Florida line, property of C. E. Clanton; auger samples.	Greenish gray, very plastic, waxy, trace of grit.	8	4	Top 6 inches	1.0	1.1	1.1	1.1	1.2	2.1	2.6	2.7	5	4	1	25
					3 feet below top	1.0	1.1	1.1	1.1	1.3	2.4	2.7	3.6	5	4	1	30
					5.4 feet below top	.8	.8	.8	.8	1.1	1.5	2.5	3.5	5	4	1	30
					8.3 feet below top	1.1	1.2	1.3	1.3	1.1	2.3	2.8	3.5	4	5	1	25

Bleach ratings of clay samples from Georgia—Continued

Miocene clays—Continued

Station No.	Location	Description of bed: Character	Thickness	Position of sample in bed	Bleach rating: Raw G	Raw Y	Raw R	Raw B	Acid-treated G	Acid-treated Y	Acid-treated R	Acid-treated B	Acid-soluble: Fe	Al	Ca	Off (percent)
			Ft. in.													
72	Brooks County; same general locality as station 71, about 0.5 mile south on county road; auger sample.	Gray, mottled red and yellow, somewhat waxy, very sandy.	2 0	Composite	1.1	1.3	1.5	1.7	1.1	1.6	1.8	2.0	4	6	0	25
73	Colquitt County; Georgia Highway 37, 9.6 miles west of courthouse in Moultrie; auger samples except top 1 foot.	Gray, mottled brown, waxy, sandy	5 0	Top 1 foot	.5	.6	.6	.6	1.3	2.0	2.7	3.2	5	5	0	25
				3 feet below top	.3	.4	.4	.4	1.4	2.2	2.4	2.5	4	6	Tr.	25
				5 feet below top	.3	.4	.4	.4	1.2	1.9	2.2	2.6	5	5	Tr.	30
		Gray, mottled brown, waxy; upper 1 foot contains beds of sand about 4 inches thick.	3 0	2.6 feet below top	.5	.6	.6	.6	1.3	2.1	2.6	3.1	5	4	1	30
74	Crisp County; U. S. Highway 280, 2.4 miles southeast of courthouse in Cordele; auger samples. See report on this locality by Bay (p. 276).	Light gray, waxy	3 3	Top 1 foot	.6	.7	.8	.8	1.1	1.9	2.2	2.3	5	5	Tr.	30
			3	feet below top	.6	.7	.8	.9	1.6	1.8	1.9	1.9	5	5	Tr.	20

Chapter 10.—PRELIMINARY INVESTIGATION OF FLORIDA BLEACHING CLAYS

By Harry X. Bay and Arthur C. Munyan

INTRODUCTION

By G. R. Mansfield

Information about the program of the Geological Survey relative to the study of bleaching clays is contained in the introductory chapter of this volume (pp. 1–22), together with an account of the history, uses, origin, and distribution of such clays and the methods employed in their laboratory study and rating. The study of bleaching clays in Florida was made possible by two successive allotments of Public Works funds to the Geological Survey, in all about $2,000. Field work under the first allotment was done in November and December 1934 by Mr. Bay and under the second allotment in April and May 1935 by Mr. Munyan.

PURPOSE AND SCOPE OF INVESTIGATION

The purpose of the investigation was to obtain available information regarding the bleaching-clay mines operating in the State, to search for extensions of the known productive deposits, to study other geologic formations in the hope of finding new possibly productive deposits of quality equal to or better than those now utilized, to gain some idea of the extent and character of any such new deposits, and to lay the foundation for possible further detailed studies.

The investigation was chiefly a reconnaissance of several geologic formations considered to offer fair promise of new discoveries.

Mr. Bay's investigations involved chiefly the study of the clay horizons of the Vicksburg group (Oligocene) in Jackson County and of the Hawthorn formation (Miocene) in Alachua, Gadsden, Jackson, Jefferson, and Marion Counties. Mr. Munyan's investigation was a continuation of Mr. Bay's and was chiefly an attempt to find activable clays. The larger part of his time was spent in sampling the Oligocene and Miocene, chiefly in Gadsden, Holmes, Jackson, Jefferson, Leon, Madison, and Washington Counties. Mr. Bay had discovered some high-grade activable clay in the Marianna district and Mr. Munyan spent considerable time in getting more information about that bed.

METHODS OF WORK

The geologic formations mentioned were studied at all road cuts and stream cuts available within the limits of time imposed by the allotted funds. This study was supplemented by borings with a 3-inch Iwan cup auger equipped with enough lengths of ¾-inch pipe to reach depths of about 30 feet. Two laborers were employed for this work. The samples collected from outcrops and borings were submitted to the laboratories of the Geological Survey in Washington for testing.

GENERAL RESULTS OBTAINED

The objectives just stated were substantially realized. In particular the investigation led to the discovery of hitherto unrecognized high-grade activable bentonitic(?) clay in Holmes, Jackson, Washington, Leon, and Jefferson Counties. All these areas are worthy of detailed investigation, and some of the deposits are apparently large enough to justify large-scale commercial operation. Thus a new item of potential economic value has been added to Florida's list of exploitable mineral resources.

ACKNOWLEDGMENTS

Thanks are due to the Superior Earth Co., Ocala, Fla.; the Floridin Co., Quincy, Fla.; and the Midway Fuller's Earth Co., Midway, Fla., for information concerning their operations. Mr. John Purdon, assistant agricultural and industrial agent for the Atlantic Coast Line, rendered assistance in the field. Valuable aid was also given by Messrs. Herman Gunter and F. C. Westendick, of the Florida Geological Survey. All samples collected were tested by P. G. Nutting in the laboratories of the Geological Survey. C. W. Cooke, of the same organization, gave counsel and aid in stratigraphic and other problems in the field.

THE BLEACHING CLAYS OF FLORIDA

By Harry X. Bay

TYPES AND DISTRIBUTION OF DEPOSITS

Bleaching clays of both the naturally active and activable types occur in Florida, but only the naturally active clay is being produced. As stated on page 4, Florida entered the fuller's earth field at an early date and for many years has contributed a considerable percentage of the country's total output. The entire production has been derived from the Hawthorn formation, which has been mined chiefly in Gadsden County. Some years ago fuller's earth was mined in Manatee County, and in recent years a mine in Marion County has been active.

The most extensive development of the Hawthorn fuller's earth is found in Gadsden County, much of which is underlain by this material. Two companies are operating in Gadsden County—The Floridin Co., with mines at Quincy and Jamieson, and the Midway Fuller's Earth Co., at Midway. Isolated thick deposits of fuller's earth are found in Marion County, and the Superior Earth Co. is producing clay from one of these northwest of Ocala. Naturally active clay is also known to occur in the Hawthorn formation in Alachua, Jackson, Jefferson, Leon, Liberty, and Manatee Counties. Some beds of the Hawthorn clay are not naturally active but are distinctly activable, as noted, for example, in Jefferson County.

In addition to the extensive deposits of high-grade naturally active clay in the Hawthorn formation, there are in the Vicksburg group beds of activable material which have sufficiently strong bleaching properties to be of commercial interest. These beds are thought to be correlative with similar beds in Georgia and Alabama and may possibly have been laid down simultaneously with the extensive bentonite (?) beds in the Vicksburg of Mississippi.

OLIGOCENE DEPOSITS—VICKSBURG GROUP

Irregular beds of bentonitic material are associated with the limestones of the Vicksburg group in Jackson County, Fla. These beds consist of iron-stained pale-green to greenish-gray unctuous waxy plastic to brittle or mealy, more or less sandy clay which is usually somewhat blackened by a manganiferous stain. The exact stratigraphic position has not been determined, but this material is thought to be of late Vicksburg or post-Vicksburg age. These bentonitic (?) clays are rather common in the area mapped [70] as Byram marl (upper Vicksburg) in south-central Jackson County and are also found overlying the older Vicksburg beds to the north and west.

The clay of the Vicksburg group in Jackson County is of particular interest because of its oil-bleaching properties. This material is not only a high-grade naturally active clay but is also sufficiently activable to make acid treatment commercially feasible. The bleach ratings of this clay compare favorably with those of the best naturally active and activable clays being marketed at the present time. Although little detailed study could be made of this area, preliminary investigations indicate that these deposits of bleaching clay are distinctly worthy of commercial attention.

The discovery of these clays in Jackson County came near the end of the time allotted for field work in the State, and consequently only a very rapid reconnaissance of them was possible. A considerable portion of the Vicksburg was traversed, however, and several exposures were located. Samples were obtained from representative beds for laboratory testing. No effort was made to outline deposits and little time was devoted to boring.

Some of the clay exposures, with notes on occurrence, bleach ratings, etc., are tabulated below. An explanation of the bleach ratings is given on page 14. The general locations from which the samples described were taken may be seen on plate 8, though the actual spots are not numbered or otherwise indicated.

[70] Cooke, C. W., and Mossom, Stuart, Geology of Florida: Florida Geol. Survey 20th Ann. Rept., pl. 2, 1929.

Observations and tests of Vicksburg clays in Jackson County, Fla.

Location	Description	Bleach rating								Remarks
		Raw				Acid-treated				
		G	Y	R	B	G	Y	R	B	
Road cut, U. S. Highway 90, east edge of Marianna. Sample taken near top of bed.	About 2½ feet clay, mottled greenish-gray and white, plastic, waxy, somewhat sandy; lies directly above Marianna limestone (early Vicksburg) and is probably lenticular.	1.0	1.1	1.1	1.1	1.6	2.4	2.6	2.8	Approaches requirements for commercial naturally active clay and is an activable clay of commercial grade.
Road cut on north side of U. S. Highway 90, 0.4 mile east of Marianna and just east of Chipola River. Sample from middle of bed 2.	*Ft.* 4. Sand, brown, and sandy clay ..... 10 3. Clay, red, sandy, streaked with dark manganese (?) stain ..... 3 2. Clay, greenish gray, waxy, slightly plastic, somewhat sandy ..... 3 1. Limestone, gray. 16	.9	1.0	1.0	1.0	1.3	2.4	2.4	2.4	Sample not sufficiently active to qualify either as naturally active or as activable clay. In both tests the initial bleach (G-water white) is high.
Road cut, U. S. Highway 90; just west of Louisville & Nashville R. R. underpass 0.2 mile west of Marianna. Sample from middle of exposed bed.	2 feet clay, greenish gray, somewhat waxy and unctuous, sandy, overlain by 5 feet brown clayey sand.	1.2	1.4	1.5	1.5	1.4	2.0	2.3	2.8	Sample exceeds minimum commercial requirements for both naturally active and activable clays.
Road cut, U. S. Highway 90, 4.3 miles west of Marianna. Sample from middle of clay exposure.	3 feet clay, light greenish gray, plastic, unctuous, waxy-appearing, sandy, with considerable manganese stain, base not exposed; overburden 4 feet of red clayey sand.	1.3	1.4	1.5	1.5	1.8	2.9	3.6	4.0	A fairly good naturally active clay and a high-grade activable clay. After partial acid leaching compares favorably with high-grade bentonite (?) of Vicksburg group in Mississippi.
Road cut, U. S. Highway 90, 5.7 miles west of Marianna. Sample from middle of exposed bed.	2 feet clay, pale green, unctuous, waxy, nonplastic, grit-free, base not exposed; overburden 10 feet brown sandy and pebbly clay.	.6	.6	.6	.6	1.5	1.7	1.8	1.8	The initial bleach (G) of the treated clay is high, but the color range is low. The material is not of commercial interest as a naturally active clay.
Right of way, State Highway 20, 1.7 *miles south* of Cottondale. Auger samples from top, middle, and base, bed 2.	*Ft. in.* 3. Clay, red, plastic; a few small iron concretions ..... 3 6 2. Clay, mottled red and green, slightly plastic and sandy ..... 9 6 1. Same, but very sandy. 13	1.2 1.3 1.3	1.5 1.8 1.6	1.6 1.9 1.7	1.6 2.0 1.8	1.6 1.7 1.5	2.6 2.6 2.5	3.2 3.4 3.0	3.8 4.0 3.6	In raw state the bleaching power of this 10-foot section of clay compares favorably with that of commercial fuller's earth of the Hawthorn formation. After acid treatment it is a highly efficient activable clay.

Road cut, State Highway 20, 0.1 mile south of Alford. Sample from middle of exposed section.	3 feet clay, mottled purple, gray, tan, and brown, slightly plastic, sandy.	1.0	1.1	1.2	1.2	1.2	1.6	2.1	2.4	This clay meets requirements for a naturally active clay but is not sufficiently active after acid treatment to be of commercial interest as an activable clay.
Cut on Atlantic & St. Andrews Bay R. R. 0.8 mile south of Alford. (Same as Munyan's station 32.) Samples from top, middle, and base of bed 2.	3. Sand, reddish brown, and clay with many small iron concretions and white siliceous nodules near base. Lower foot very dark from manganese stains ..... *Ft.* 8 *in.*	.5	.6	.6	.6	1.7	2.1	2.2	2.3	Sequence of beds similar to that of bentonitic (?) beds in Vicksburg group, Smith County, Miss. There bentonite (?) layer generally associated with black (manganese) bands above and below. White siliceous nodules also common in overlying clayey sands and sandy clays. (Munyan places this clay in the Tampa limestone (Miocene; see p. 323). Efficiency too low for commercial use. Initial bleach of treated clay is high, but color separation is poor. Possibly unweathered samples would yield higher ratings. Favorable location on railroad.
	2. Clay, mottled gray and tan, unctuous, waxy, nonplastic, mealy, slightly sandy 2 6	.5	.5	.5	.5	1.5	1.6	1.6	1.6	
	1. Sand, brown, clayey, dark manganese stain. 10 6	.5	.5	.5	.5	1.4	1.9	2.0	2.1	
Road cut 0.8 mile south of Marianna on Frink road. Sample from middle of exposed section on east side of road.	2 feet clay, mottled red and gray, plastic, waxy, slightly sandy; base not exposed; overburden brown sandy clay.	1.4	1.9	2.0	2.1	2.0	2.9	3.2	3.4	A good commercial grade; either as naturally active or activable clay. Initial bleach high and color separation good.
Road cut 0.3 mile east of Pittman Hill School and 1.0 mile east of Clendennon village. School is about 8 miles south of Marianna. Sample from middle of bed 1.	3. Sand, red, clayey; occasional iron concretions and white siliceous nodules toward base ..... *Ft.* 3 2. Clay, mottled red and gray, plastic, sandy. 4 1. Clay, greenish gray, unctuous, waxy, slightly plastic and sandy; base not exposed ..... 3+ 10+	1.0	1.1	1.1	1.1	2.0	2.9	3.1	3.2	Sample is an activable clay of commercial grade.
Road cut, U. S. Highway 231, 1.5 miles northwest of Marianna. Sample from middle of clay bed.	2½ feet clay, greenish gray, waxy-appearing, plastic; lies directly on Marianna limestone; overlain by thin bed of sandy clay with small iron concretions.	.9	1.0	1.1	1.1	1.9	2.9	3.0	3.0	Sample is well above minimum requirement of commercial activable clays.
Road cut, U. S. Highway 231, 2.5 miles northwest of Marianna. Sample from middle of bed.	1 foot clay, mottled gray, tan, and pink, laminated, plastic, somewhat sandy; lies on Marianna limestone; overlain by 4 feet red to brown sandy clay with many large iron concretions.	1.1	1.4	1.6	1.7	1.8	2.9	3.2	3.5	Clay is of commercial grade in both natural and treated states; rates high as an activable bleaching clay.
Road cut, U. S. Highway 231, 3.6 miles northwest of Marianna. Sample from middle of exposed bed.	2½ feet clay, gray to nearly white, unctuous, mealy, grit-free; overlies Marianna limestone; overburden yellow to brown clayey sand with many small iron concretions.	1.0	1.2	1.3	1.3	2.0	2.9	3.3	3.5	Material is a fairly good fuller's earth and a high-grade activable bleaching clay.
Road cut, U. S. Highway 231, 9.9 miles northwest of Marianna. Sample from middle of bed.	1 foot clay, tan to gray, slightly plastic, waxy-appearing, grit-free, somewhat darkened by manganese stain; base not exposed.	.8	.9	.9	.9	2.0	3.0	3.3	3.5	Clay is sufficiently activable to be of commercial interest.

Observations and tests of Vicksburg clays in Jackson County, Fla.—Continued

Location	Description	Ft.	Bleach rating: Raw G	Raw Y	Raw R	Raw B	Acid-treated G	Acid-treated Y	Acid-treated R	Acid-treated B	Remarks
Road cut, State Highway 90, 1 mile southwest of Marianna. Sample from middle of exposed clay bed.	3 ft. clay, greenish gray, waxy, plastic, somewhat sandy; base not exposed. Overburden 4 feet sand, yellowish to brown, clayey. Contains small iron concretions, large limonite masses, and occasional white siliceous nodules near base.		1.5	2.0	2.2	2.3	1.6	2.4	2.6	2.9	An exceptionally good fuller's earth, ranking well above many of the present commercial clays; also meets commercial requirements for activable bleaching clay.
Road cut, 3.5 miles southwest of Marianna on Kynesville road. Sample from top, middle, and lower parts of bed 1.	3. Sand, red, clayey; has many small iron concretions	1	1.3	1.6	1.7	1.7	1.7	2.8	3.1	3.3	Samples from top and bottom of bed are commercial material in either raw or treated state. Middle sample, by itself, not of commercial grade, but combined with the other two helps constitute an 8-foot bed of commercial grade.
	2. Clay, yellowish to tan, somewhat waxy, plastic, very sandy; contains iron concretions and siliceous nodules	3	1.0	1.1	1.1	1.1	1.8	2.5	2.5	2.5	
	1. Clay, greenish gray, waxy, unctuous, slightly plastic and sandy; base not exposed but bed becomes more sandy toward base	4+ 8+	1.4	1.6	1.6	1.6	2.0	3.2	3.7	3.9	
Road cut, State Highway 20; 2.8 miles north of Cottondale. Sample from middle of clay bed.	3. Sand, red, clayey, with many iron concretions	4	1.0	1.3	1.4	1.6	1.2	1.6	1.9	2.2	A commercial grade of fuller's earth somewhat improved by acid leaching. However, the improvement is not sufficient to justify acid treatment.
	2. Clay, mottled gray, yellow and pink, plastic, waxy, grit-free, some manganese stain	3									
	1. Limestone, soft, gray	7									

MIOCENE DEPOSITS—HAWTHORN FORMATION

The Hawthorn is one of the most widely distributed formations in Florida. It extends from the Apalachicola River eastward to Jacksonville and as far south as DeSoto County. The Hawthorn in Florida has been described by Cooke and Mossom [71] as follows:

The most persistent component of the Hawthorn formation is white or cream-colored sandy limestone containing brown grains of phosphorite. Rock of this kind is widely distributed in the Peninsula and the northern part of the State but is rarely seen in natural exposures, for it readily disintegrates into sand. An intermediate product of disintegration is gray or white, very light, pumicelike vesicular sandstone, from which the lime and phosphate have been dissolved, leaving smooth, rounded blebs in place of the phosphatic grains. Rock of this kind, usually in small lumps, caps many hills.

Green or gray siliceous clay or fuller's earth forms an important part of the Hawthorn in Gadsden County and is present in less abundance in the Peninsula.

During the course of this investigation clay beds of the Hawthorn were examined in Alachua, Gadsden, Jackson, Jefferson, and Marion Counties.

ALACHUA COUNTY

The northeastern half of Alachua County is underlain by the Hawthorn formation, but the county is largely a level plain and exposures are rare.

Fuller's earth, light greenish gray, very hard and brittle, slightly sandy, and silicified is exposed in a road cut about 1 mile north of Micanopy on United States Highway 41. Samples taken from this 7-foot exposure yielded the following bleach ratings:

Sample	Raw				Acid-treated			
	G	Y	R	B	G	Y	R	B
Top	1.1	1.4	1.5	1.6	0.5	0.6	0.8	1.1
Middle	1.0	1.3	1.5	1.8	0.7	0.9	1.1	1.3
Base	0.9	1.2	1.4	1.7	0.8	0.9	1.0	1.2

This is shown to be a very good grade of fuller's earth, and the quality is consistent throughout the exposed thickness. The bleaching power is reduced by acid treatment.

Cooke and Mossom [72] report the occurrence of fuller's earth in the Devil's Mill Hopper, 6 miles northwest of Gainesville, and at Alachua Sink, 3¼ miles south-southeast of Gainesville.

GADSDEN COUNTY

The Hawthorn formation in Gadsden County has received much attention because of its great deposits of fuller's earth. Practically the whole county is underlain by fuller's earth, the exposed edges of

[71] Cooke, C. W., and Mossom, Stuart, Geology of Florida: Florida Geol. Survey, 20th Ann. Rept., pp. 115–116, 1929.

[72] Cooke, C. W., and Mossom, Stuart, op. cit., pp. 129–130.

the strata forming an irregular band that borders most of the streams. The following description is quoted from Sellards and Gunter's account [73] of the fuller's earth of Gadsden County:

Along Little River and its tributaries, Quincy, Willacoochee, Attapulgus, and Swamp Creeks, outcrops are very frequent from the Georgia line across the county, exposures occurring, in fact, wherever excavations for public roads or for railroads or where rapid surface wash had removed the soil and residual material. The dip of the fuller's earth stratum from the north to the south line of the county along this river is but slight and apparently scarcely equals the fall of the stream beds. At the Georgia line on Willacoochee Creek the fuller's earth stratum lies above the stream bed about 15 feet. Outcrops seen on Swamp and Attapulgus Creeks within 1 to 2 miles of the Georgia line lie at about the same level above the stream beds. In the section at Nicholson, on Little River, formed by the union of these two streams and about 7 miles south of the State line, the lowest fuller's earth seen lies 20 feet above the bed of the stream. At Midway, near the southern part of the county, the fuller's earth lies along small streams (sec. 8, T. 1 N., R. 2 W.), reaching back as much as 2 miles from Ocklocknee River. At Jackson's Bluff, the southernmost exposure of fuller's earth seen, the stratum lies above the bed of the Ocklocknee about 25 feet. Beyond this point the dip of the strata is doubtless more rapid than the fall of the stream, as the bluffs die out toward the coast.

In the western part of this county the fuller's earth stratum is cut into by the headwaters of both the North and South Branches of Mosquito Creek, and farther south by the tributaries to Flat Creek and Crooked Creek; also in Liberty County by the headwaters of Rock Creek and Sweetwater Creek. While the tributaries of Little River, flowing in a general north and south direction, flow parallel with the fuller's earth, the tributaries of the Apalachicola, with much steeper gradient, cut across the edge of the fuller's earth strata and into the sands, marls, and limestones lying below. Although in general horizontal, minor folds have been observed in the fuller's earth at several localities.

Throughout most of Gadsden County the two beds of fuller's earth are separated by very sandy beds called the "middle burden," which bear vertebrate fossils. The present commercial operations are located near Quincy, at Jamieson, and at Midway.

Floridin Co.'s mines.—Some years ago the Floridin Co. produced fuller's earth at a place that is now known as Old Jamieson. This mine was about 2 miles west of Mount Pleasant on the Seaboard Air Line Railway. The old mine excavation is now covered by a dense growth of vegetation, and the walls are badly slumped, so that the clay bed is hidden. About 2½ feet of clay, pale bluish green, hard, brittle, and somewhat sandy, is exposed in a small stream which traverses the old workings. Bleach ratings of samples from this mine are given on the following page.

[73] Sellards, E. H., and Gunter, H., The fuller's earth deposits of Gadsden County, Fla: Florida Geol. Survey, 2d Ann. Rept., pp. 281-282, 1909.

Sample	Raw				Acid-treated			
	G	Y	R	B	G	Y	R	B
Top	0.9	1.1	1.2	1.3	0.7	0.9	1.1	1.2
Middle	0.7	1.0	1.1	1.2	0.7	1.0	1.1	1.3

Judged by present commercial standards this material is a naturally active bleaching clay of very low grade.

The Floridin Co. is now producing clay at Quincy and Jamieson. A large mill at Quincy receives clay from the valley of Quincy Creek about 1.7 miles to the northwest. The raw clay is transported from the mine to the mill over a company railroad. Fuller's earth is being mined along both sides of the creek, and clay is now being taken from three excavations—the A. S. T. mine, the Graves Extension No. 2 mine, and the North Graves mine.

The A. S. T. excavation is on the east side of Quincy Creek, where the following section was measured:

	Ft.	*in.*
4. Fuller's earth, greenish gray to bluish green, unctuous, waxy, hard and brittle	2	6
3. Sand and very sandy fuller's earth which carries scattered fossils	4	0
2. Fuller's earth, greenish gray, waxy, very hard and brittle, with a few thin limy streaks and considerable manganese stain	6	0
1. Fuller's earth, greenish gray, very sandy, which grades downward into clayey sand.		

Bleach ratings of samples from beds 2 and 4 are given below.

Sample	Raw				Acid-treated			
	G	Y	R	B	G	Y	R	B
Bed 4: Middle	1.0	1.3	1.6	1.7	0.6	0.8	1.0	1.3
Bed 2:								
Top	1.1	1.4	1.7	1.8	.6	.6	.7	1.1
Middle	1.2	1.6	1.9	2.1	.6	.9	1.2	1.6
Base	1.3	1.8	2.1	2.3	.6	.9	1.2	1.6

The bleach ratings show this to be a high-grade fuller's earth, with the lower bed somewhat more efficient than the upper. The bleaching efficiency appears to increase downward through the stratum and is somewhat reduced by acid leaching.

The Graves Extension No. 2 mine is on a small tributary that enters Quincy Creek from the west. In this excavation the upper fuller's earth bed is less pure than that in the A. S. T. mine, and consequently clay is removed from the lower bed only. Here the commercial clay maintains an average thickness of about 6 feet and consists of greenish-gray unctuous, waxy, hard and brittle, grit-free fuller's earth, with much manganese staining.

The bleach ratings are as follows:

Sample	Raw				Acid-treated			
	G	Y	R	B	G	Y	R	B
Top	1.2	1.4	1.5	1.5	0.6	1.0	1.2	1.3
Middle	1.2	1.4	1.5	1.5	.7	1.0	1.3	1.7

These ratings show the efficiency of this clay bed to be uniform. The material appears to be somewhat less active than that tested from the A. S. T. mine.

The northernmost excavation is the North Graves mine, which shows about 30 inches of hard and brittle fuller's earth at the upper horizon. Separated from the upper zone by about 3 feet of sand and sandy fuller's earth is the lower bed which reaches a thickness of about 7 feet and consists of greenish-gray unctuous, waxy, hard and brittle, grit-free fuller's earth that becomes bluish in color toward the base. The bleach ratings are given below:

Sample	Raw				Acid-treated			
	G	Y	R	B	G	Y	R	B
Upper bed, middle	1.0	1.3	1.4	1.5	0.7	0.9	1.2	1.4
Lower bed:								
Top	1.4	1.8	1.9	2.0	.7	.9	1.1	1.5
Middle	1.4	1.6	1.8	2.0	.7	1.0	1.2	1.4
Base	.9	1.3	1.5	1.7	.6	.9	1.1	1.3

The bleaching efficiency of the upper bed is somewhat less than that of the lower bed. The upper and middle parts of the lower bed appear to be the most efficient, but the natural bleaching properties are consistently good throughout the section. Acid treating proves detrimental to the bleaching action of this clay.

Clay of commercial grade is reported to continue northward along Quincy Creek for more than half a mile beyond the North Graves mine.

The Jamieson branch of the Floridin Co. is producing clay from a mine near the confluence of Attapulgus and Swamp Creeks. This No. 1 mine exposed a single bed of fuller's earth which reaches a thickness of about 10 feet. The fuller's earth is greenish gray, unctuous, waxy, hard and brittle, and grit-free. Underlying this bed is a bed of very sandy fuller's earth which grades downward into a clayey sand. An old sand-filled stream channel cuts through the fuller's earth bed at this locality. The bleach ratings of samples from the 10-foot bed are as follows:

Sample	Raw				Acid-treated			
	G	Y	R	B	G	Y	R	B
Top	0.9	1.2	1.3	1.4	0.6	0.8	1.0	1.1
Middle	1.0	1.3	1.5	1.6	.8	.8	1.0	1.1
Base	.8	1.0	1.2	1.4	.7	.9	1.1	1.4

The bleaching qualities of the samples from this mine are shown to be inferior to those of the samples from the Quincy mines, operated by the same company (tests given above.)

Another mine in the Jamieson group, the Kemp, which is about 1¾ miles north of Jamieson, reveals about 10 feet of greenish-gray unctuous, waxy, grit-free fuller's earth with scattered thin limy streaks. This fuller's earth appears to be considerably softer than that in the Jamieson No. 1 mine and the Quincy group. There is only one fuller's earth bed at this locality. The underlying material is a very sandy fuller's earth which grades downward into sand. The bleach ratings of samples from this mine are given below:

Sample	Raw				Acid-treated			
	G	Y	R	B	G	Y	R	B
Top	1.1	1.5	1.6	1.7	0.7	1.0	1.1	1.4
Middle	1.0	1.4	1.5	1.6	.9	1.2	1.3	1.4
Base	.7	1.0	1.2	1.3	.6	.9	1.1	1.2

The upper and middle parts of the 10-foot bed in the Kemp mine are good grades of fuller's earth.

Midway Fuller's Earth Co.—The Midway Fuller's Earth Co. has been producing fuller's earth at Midway, Fla., for many years. The mines are along Hunter Creek, a tributary to the Ochlockonee River, in the east-central part of Gadsden County, and are served by the Seaboard Air Line Railway. The fuller's earth stratum reaches a thickness of 12 to 15 feet and consists of light to greenish gray unctuous, waxy, very hard and brittle, essentially grit-free clay. Mine pits 1 and 6 are being operated now, and the overburden at these pits consists of 20 to 25 feet of brown clayey sand, which is removed by hydraulic methods. The bleach ratings of clay samples from these pits are as follows:

Sample	Raw				Acid-treated			
	G	Y	R	B	G	Y	R	B
Pit 1:								
Top	1.3	1.6	1.6	1.6	0.8	1.1	1.4	1.8
Middle	1.0	1.3	1.5	1.8	.7	1.0	1.3	1.6
Base	1.0	1.3	1.5	1.8	.4	.6	.9	1.3
Pit 6:								
4 feet from top	1.2	1.5	1.6	1.9	.9	1.0	1.2	1.6
4 feet from base	1.1	1.5	1.7	1.8	.7	1.0	1.3	1.6

The clay beds in both pits yield consistently good fuller's earth. In all samples except the one from the top of the bed in pit 1, the bleaching efficiency is reduced by acid treatment. This sample after acid treatment shows a reduced efficiency except in the final bleach column.

An auger hole bored on the south side of Willacoochee Creek 4½ miles north of Quincy revealed the following section:

	Ft.	in.
4. Clay, mottled red and gray, slightly sandy, plastic	2	6
3. Fuller's earth, light gray, plastic ("shortbread")		6
2. Fuller's earth, light gray, unctuous, waxy, very hard and brittle, grit-free	3	6
1. Sand, gray, very hard, clayey.		

Bleach ratings of clay samples from bed 2 of this boring are as follows:

Sample	Raw				Acid-treated			
	G	Y	R	B	G	Y	R	B
Top	1.1	1.4	1.5	1.6	0.7	0.9	1.1	1.3
Middle	1.0	1.2	1.4	1.6	.6	.8	1.0	1.2
Base	.9	1.1	1.2	1.3	.8	1.0	1.2	1.4

The upper and middle parts of this 3½-foot bed of fuller's earth are better than the lower part.

The section given below was penetrated in a prospect hole bored on the Morgan property in the valley of Willacoochee Creek, 5½ miles northeast of Quincy on the Jamieson road.

	Feet
6. Sand, yellow, fine-grained	1
5. Clay, gray, plastic, sandy	2
4. Clay ("shortbread"), greenish gray, unctuous, plastic, sandy	2
3. Fuller's earth, pale greenish gray, unctuous, hard and brittle, grit-free	3
2. Fuller's earth, gray, hard, highly sandy	1
1. Sand, clayey.	

The bleach ratings of samples from beds 3 and 4 are given below.

	Raw				Acid-treated			
	G	Y	R	B	G	Y	R	B
Bed 4:								
Top	0.9	1.0	1.0	1.0	1.0	1.5	1.8	2.0
1 foot from top	1.0	1.1	1.1	1.2	1.0	1.5	1.8	2.1
Bed 3:								
Top	1.1	1.4	1.6	1.7	.7	.9	1.0	1.2
1 foot from top	1.1	1.4	1.5	1.7	.7	.9	1.0	1.2
2 feet from top	1.0	1.4	1.5	1.7	.7	.9	1.1	1.2

The bleach ratings indicate that two types of clay are present in this section—(1) the plastic "shortbread" of bed 4, which is somewhat active in the natural state and is also activable, and (2) the true hard and brittle nonplastic fuller's earth of bed 3, which is decidedly naturally active but not activable. The clay of bed 4 is not sufficiently activable to warrant acid treatment.

Exposures of fuller's earth were noted in road cuts along United States Highway 90 at points 2.7 and 3.1 miles east of Quincy. The clay is similar to that described above, and the bleaching properties compare favorably with those of the commercial fuller's earths being produced in Gadsden County.

JACKSON COUNTY

Thin beds of clay occur in the basal part of the Hawthorn formation near Sneads, in Jackson County. This clay is of the naturally active type, and certain samples tested were sufficiently active to be classed as low-grade fuller's earth.

A road cut on the Noah Glisson property, 2.7 miles southwest of Sneads on the Blountstown road, reveals 1½ feet of greenish-gray waxy, brittle sandy clay lying directly above light-gray limestone (Tampa?). A sample from the middle of this exposed clay bed was found from the following bleach ratings to be a low-grade fuller's earth:

Raw				Acid-treated			
G	Y	R	B	G	Y	R	B
1.0	1.2	1.3	1.4	0.8	1.0	1.1	1.2

A 3-foot bed of mottled light and dark gray sandy clay is exposed in a ditch at the side of United States Highway 90 1.4 miles west of Sneads. Although of the naturally active type, this clay does not qualify as a commercial bleaching clay.

An auger sample from a 3-foot bed of tan plastic sandy clay 4.3 miles south of Sneads on the Blountstown road gave the following bleach rating:

Raw				Acid-treated			
G	Y	R	B	G	Y	R	B
1.2	1.3	1.4	1.4	1.6	2.5	2.6	2.6

This plastic clay may be classed as a low-grade fuller's earth that is somewhat activable.

JEFFERSON COUNTY

Thin beds of activable clay are associated with the thick red and yellow clayey sands of the Hawthorn formation in Jefferson County.

In a road cut 1.0 mile north of the courthouse at Monticello 2 feet of gray plastic laminated sandy clay is exposed. Tests of a sample from the middle of this bed show it to be of the activable type but not of commercial quality, as indicated below.

Raw				Acid-treated			
G	Y	R	B	G	Y	R	B
0.3	0.4	0.4	0.4	1.0	1.8	1.9	2.0

A sample obtained from a well near the dwelling of J. W. H. McClellan, 7.4 miles southwest of Monticello on State Highway 96, proved to be an activable clay of commercial quality. This material is light tan, plastic, and slightly sandy. It is reported that 9 feet of this material was penetrated in digging the well. The bleach rating of this clay is as follows:

Raw				Acid-treated			
G	Y	R	B	G	Y	R	B
0.3	0.4	0.4	0.4	1.8	2.8	3.2	3.2

Samples taken from a second well on this farm proved to be much lower in activable bleaching qualities and do not qualify as commercial clay. The clay bed on the McClellan property is thought to be confined to a very small area.

A sample of gray plastic clay from a well on the property of Mrs. L. N. Morris, 6.9 miles southwest of Monticello on State Highway 96, yielded the following bleach rating:

Raw				Acid-treated			
G	Y	R	B	G	Y	R	B
0.9	1.0	1.0	1.0	1.2	1.8	2.1	2.2

Although of the activable type, this clay is not sufficiently active after acid treatment to be of commercial interest.

Activable clays of noncommercial grade were found on the property of Lewis Jones, 1½ miles north of Lamont, at Mount Marrilla Church, and in a road cut 3 miles northeast of Lamont on United States Highway 19.

MANATEE COUNTY

Fuller's earth is known to occur in the Hawthorn formation near Ellenton, in Manatee County, and a mine was in operation at this locality some years ago. The short time allowable for this investigation did not permit an examination of the clays in Manatee County.

MARION COUNTY

Thick beds of fuller's earth occur in the Hawthorn formation which is exposed discontinuously in west-central and northwestern Marion County. The Superior Earth Co. is producing naturally active clay from the Hawthorn formation at a place some 5 miles south-southeast of Fairfield. A generalized section of the north wall of the mine is as follows:

	Feet
7. Sand, pale green to light gray, somewhat indurated, clayey, medium-grained; contains some angular fragments of green waxy clay	8½
6. Clay, green, waxy, slightly plastic, grit-free	4
5. Sand, pale greenish gray, clayey, medium- to coarse-grained, with a few fossil bones	6
4. Clay, light gray with green streaks, thin-bedded, partly silicified, becoming distinctly sandy in lower 3 feet	15
3. Clay, gray to brownish gray, very sandy ("middle burden")	3
2. Clay, light gray, more or less silicified; partly indurated, sandy toward base	8
1. Ocala limestone (?), not exposed.	

Bleach ratings of samples from beds 2, 3, 4, and 6 are given in the following table:

	Raw				Acid-treated			
	G	Y	R	B	G	Y	R	B
Bed 6, 2 feet from top	0.8	0.9	1.0	1.0	0.7	1.0	1.2	1.6
Bed 4:								
Top	1.1	1.3	1.4	1.4	.6	.8	1.0	1.3
3 feet from top	1.0	1.2	1.3	1.4	.6	.7	.9	1.2
6 feet from top	1.0	1.2	1.4	1.5	.6	.7	.9	1.2
9 feet from top	1.1	1.5	1.6	1.6	.8	.9	1.0	1.0
12 feet from top	1.0	1.2	1.3	1.4	.6	.8	.9	1.1
Bed 3, 1 foot from top	1.1	1.4	1.5	1.5	.7	.9	1.1	1.1
Bed 2:								
1 foot from top	1.1	1.4	1.5	1.6	.8	.9	1.0	1.2
4 feet from top	1.0	1.2	1.3	1.4	.6	.8	1.1	1.3
7 feet from top	.9	1.1	1.2	1.3	.7	1.0	1.1	1.2

The thick section of fuller's earth being worked in this mine is shown to have good bleaching properties and to be fairly uniform in quality throughout. It is the thickest body of commercial bleaching clay now known in the State. The present operation is confined to a relatively small area, and the extent of the deposit was not determined in this investigation.

An auger hole 1.4 miles north of the Superior Earth Co.'s mine on the Fairfield road, on the property of J. Waldron (?), revealed a bed of bleaching clay which shows promise. The section is as follows:

	Feet
6. Clay, brown, sandy	1
5. Clay, greenish gray, sandy, waxy, plastic	5
4. Sand, greenish gray, clayey, streaked with green waxy clay	5½
3. Clay, greenish gray, hard and brittle, waxy, partly silicified with thin sand streaks	3
2. Clay, brown, sandy (resembles "middle burden" of Superior Earth Co.'s mine)	3
1. Clay, greenish gray, indurated, silicified (too hard to be penetrated by available drilling equipment).	

Samples were collected from beds 1, 3, and 5, and the oil-bleach ratings of these samples are given below:

	Raw				Acid-treated			
	G	Y	R	B	G	Y	R	B
Bed 5:								
Top	0.8	1.1	1.2	1.3	0.8	1.0	1.2	1.3
4 feet from top	.9	1.0	1.1	1.2	1.3	2.1	2.4	2.5
Bed 3, 1 foot from top	1.1	1.4	1.5	1.6	.6	.7	.8	1.0
Bed 1, top	1.0	1.3	1.4	1.5	.8	1.0	1.3	1.6

The lower part of the plastic bed (bed 5) is of the activable type and approaches, but does not reach, the minimum requirement for commercial activable clay. The samples from beds 1 and 3 are good, naturally active clays and are of commercial quality.

A road cut 2.6 miles north of the Superior Earth Co.'s mine on the Fairfield road exposes 3 feet of indurated mottled greenish-gray and white brittle, flintlike clay that possesses high natural bleaching properties. A sample from the middle of this 3-foot exposure yielded the following bleach rating:

Raw				Acid-treated			
G	Y	R	B	G	Y	R	B
1.2	1.5	1.8	2.0	0.7	0.9	1.1	1.5

The following section of clay is exposed in a ditch on the south side of State Highway 24, 1.7 miles northwest of Flemington:

	Feet
2. Clay, greenish gray, and mottled brown and gray, waxy, slightly sandy, plastic	3
1. Clay, greenish gray, hard and brittle, unctuous, waxy, very slightly sandy, partly silicified	3+

Bleach ratings of samples from this exposure follow:

	Raw				Acid-treated			
	G	Y	R	B	G	Y	R	B
Bed 2:								
Top	0.9	1.1	1.2	1.2	0.7	1.0	1.2	1.5
2 feet from top	1.0	1.2	1.3	1.4	.7	.9	1.1	1.4
Bed 1:								
1 foot from top	1.3	1.6	1.7	1.8	.6	.7	.8	1.0
3 feet from top	1.0	1.3	1.4	1.5	.6	.7	.9	1.2

Both beds are sufficiently active in the natural state to be of commercial interest as bleaching clays, and the lower one is somewhat better than the upper.

SUMMARY AND CONCLUSIONS

Naturally active and activable bleaching clays occur in Florida. Vast deposits of fuller's earth in the Miocene Hawthorn formation are extensively mined in Gadsden and Marion Counties. Activable clay in the Oligocene Vicksburg group in Jackson County is of a quality sufficiently high to warrant detailed investigation.

SUPPLEMENTAL INVESTIGATIONS OF FLORIDA BLEACHING CLAYS

By A. C. Munyan

All locations from which samples were obtained are listed in the accompanying tables, along with the bleach rating for each sample. (See pp. 327–333.) Consequently, for brevity, little mention will be made of those samples which do not attain the proposed minimum rating for commercial bleaching clays. However, all locations, regardless of the rating of the clay samples, are indicated on the accompanying map (pl. 8).

The tables are so arranged that the field stations and samples are listed in sequence under formations of Eocene, Oligocene, and Miocene age. As samples collected from the Eocene formations appear to be of no commercial interest, because of the low bleaching quality indicated in the tables, no further discussion of them is presented.

OLIGOCENE DEPOSITS

MARIANNA LIMESTONE AND OVERLYING BEDS

The Marianna limestone has been described [74] as "a soft white homogeneous, somewhat porous limestone * * * which probably does not exceed a thickness of 50 feet in Florida, * * * overlain unconformably by 22 feet of coarse orange-red pebbly sand and patches of greenish clay."

It is in this 22-foot bed above the Marianna limestone that activa-

[74] Cooke, C. W., and Mossom, Stuart, Geology of Florida: Florida Geol. Survey 20th Ann. Rept., pp. 63–66, 1929.

ble clays were found in the region near Marianna (see pl. 8). As Cooke and Mossom noted, the bed lies unconformably upon the Marianna limestone, and probably it should not be considered as of Marianna age. Sufficient data are lacking at present, however, to place its stratigraphic relationship definitely.

Seven exposures (stations F–6 to F–12) were found in the outcrop area of the Marianna limestone. Four of these—nos. 6, 7, 8, and 9—were identified as the clay bed lying unconformably upon the Marianna limestone, whereas the clay at stations 11 and 12 was not so classified in the field because bedrock was not reached with the auger.

The section at station F–10, 3.4 miles northwest of the Jackson County courthouse in Marianna, on United States Highway 231, given below, shows that the clay there forms an integral part of the Marianna limestone.

	Ft.	*in.*
4. Limestone, gray, blocky, hard, fossiliferous	0	6
3. Clay, greenish gray, waxy, gritty, fossiliferous	1	0
2. Limestone, light gray, hard, fossiliferous	0	8
1. Clay, light gray, irregularly laminated, waxy, gritty, fossiliferous	3	0

The bleach ratings of a composite sample indicate that this clay is not of commercial quality.

At station F–6, in a road cut at the junction of United States Highways 90 and 231, at the northwest edge of Marianna, the following section was obtained:

	Ft.	*in.*
11. Sand and gravel, gray, mottled brown and red, cross-bedded	20	0
10. Clay, gray, mottled red, irregularly bedded, waxy, sandy (sampled)	2	0
Top of auger hole.		
9. Clay, gray, mottled red, waxy, gritty (3 samples)	3	0
8. Clay, gray, mottled red and brown, waxy gritty		8
7. Clay, red, mottled gray and purple, waxy, gritty		8
6. Clay, red and yellow, waxy, gritty (2 samples)	3	5
5. Clay, purple, gray streaks, waxy, gritty	1	4
4. Clay, brick red, gray patches, waxy, gritty (2 samples)	4	10
3. Iron crusts, hard, irregular, interbedded with thin sand layers	4	0
2. Clay, light, green, waxy, limestone chips (sampled)	2	0
1. Limestone, white, hard, Marianna.		

Samples were taken to ascertain the value of each individual clay layer. These are indicated in the tables. The bleach ratings show that each sample is close to or above the minimum for a fuller's earth and also for activable clay, and that the bed as a whole is of high grade.

Station F–7 is 0.9 mile south of the Jackson County courthouse in Marianna, on the line between secs. 9 and 10, T. 4 N., R. 10 W. The following section is exposed:

	Ft.
3. Soil, dark brown, probably derived from underlying clay	1
2. Clay, gray, mottled brown, irregularly bedded waxy and greasy, sandy (3 samples)	15
1. Limestone, white, grayish, hard (Marianna)	(?)

Tests of samples from this exposure seem to show that the middle of the bed has a higher activable bleaching power than either the top or the base and that all are efficient fuller's earth, or naturally active clay. This result may be due to the method of sampling, in which weathered material, instead of fresh, was taken. However, the ratings may be representative, for the entire clay bed here has long been exposed to weathering.

Station F–8, 1.9 miles southwest of the courthouse in Marianna, on the Kynesville road, then half a mile north along a county road to the outcrop, shows the following section:

	Ft.	in.
9. Soil, dark brown, probably derived from underlying clay	1	0
8. Clay, gray, mottled red, waxy, sandy (3 samples)	6	0
Top of boring.		
7. Clay, same as bed 8	15	0
6. Sand, light gray, coarse-grained, clayey	3	0
5. Sand, gray and red mottled, medium-grained	1	0
4. Clay, ocherous, waxy, sandy (sampled)	2	0
3. Iron crusts, hard, irregular	1	0
2. Clay, light green, limy	1	5
1. Limestone, white, hard (Marianna)	(?)	

Tests of samples from the outcrop and bore hole at this point indicate that the clay approaches but does not quite attain the minimum requirements for commercial activable clay, but that it is a naturally active clay of fair quality.

The section exposed at station F–9, 1.7 miles southwest of the courthouse in Marianna on the Kynesville road, is as follows:

	Ft.	in.
4. Soil, dark brown, probably derived from clay below	1	0
3. Clay, gray, mottled red and brown, waxy, sandy (2 (samples)	5	0
Top of boring.		
2. Clay, greenish gray, waxy, gritty, small sand streaks (3 samples)	4	6
1. Clay, brown, ocherous, waxy, sandy, much manganese stain (sampled)	7	6

Another hole bored later, 10 feet farther east, presented this section:

	Ft.	in.
10. Soil, dark brown	1	0
9. Clay, gray, mottled red and brown, waxy, sandy	5	0
Top of boring.		
8. Clay, light gray, waxy, sandy	3	0
7. Sand, gray, medium-grained		6
6. Clay, gray, mottled, tan and red; manganese	5	6
5. Sand, brown, coarse-grained	6	0

	Ft.	in.
4. Iron crusts, hard, irregular	2	0
3. Clay, red and gray mottled, sandy, much manganese stain	1	0
2. Clay, light green, waxy, limy	1	8
1. Limestone, white, soft (Marianna)	(?)	

Samples were taken from the first boring at this station. Their bleach ratings are very close to the minimum, but one sample exceeds it.

At station F-11, 4.6 miles west of the courthouse in Marianna, on United States Highway 90, the following section occurs:

	Ft.	in.
13. Soil, dark brown	2	0
12. Clay, light gray, waxy, somewhat sandy	2	0
Top of boring.		
11. Clay, light gray, red streaks, waxy, sandy (sampled)	3	6
10. Sand, gray, mottled red, coarse-grained		4
9. Clay and sand; gray and red		8
8. Clay, greenish gray, waxy, small sand streaks (sampled)	4	0
7. Clay, green, mottled red, waxy (sampled)		10
6. Clay, green, waxy	1	2
5. Clay, light gray, waxy, gritty, thin layer limestone		8
4. Sand, light gray, coarse-grained, clayey (sampled)	2	3
3. Sand, light gray, very coarse-grained		5
2. Clay, light gray, waxy, small sand streaks (sampled)	2	4
1. Sand, light gray, coarse-grained, clayey	6	6

Samples from this bore hole have bleach ratings slightly under the lowest commercial limit. The log also indicates sand layers with the clay, which would probably be detrimental to its use.

At station 12, 7 miles west of the courthouse in Marianna on the Kynesville road, the following section is exposed:

	Ft.	in.
6. Sand, light gray, medium-grained	3	0
5. Clay, greenish gray, waxy, gritty (sampled)	2	0
4. Sand, red and gray, very coarse-grained		5
3. Clay, greenish gray, mottled red, waxy, sandy, (2 samples)	4	0
2. Clay, gray, waxy, sandy, manganese stains (sampled)	1	10
1. Clay, brown, waxy, not gritty, a few manganese stains (2 samples)	2	0

The bleach ratings for six samples from this exposure are well above the lower limit for activable clays, and one almost equals the best grade known. This clay is also naturally active and qualifies as a good fuller's earth. The base of the bed was not reached at this point, but there seems to be a similarity between this clay and that at stations 6 to 9. It is probably the same, but because the Marianna limestone was not reached, no check on the thickness was obtained, and the complete section is unknown.

A comparison of the sections at stations 6, 7, 8, 9, 11, and 12 shows a degree of similarity sufficient for a tentative correlation. The bleach ratings for the samples also support this to some extent. In general, it seems that the bed lying upon the Marianna limestone is the same at each of these stations. However, it is impossible to correlate units within the bed from the present data. This is very well illustrated by the wide variation of the sections obtained within 10 feet of one another at station 9, where sand layers appear in one auger hole and not in the other.

Although the bleach ratings of the samples indicate a high-grade deposit of bleaching clay in the Marianna region, other factors that greatly influence the value of a deposit must be considered. Much additional information is needed on the quality, thickness, and areal extent of the clay and the character and thickness of overburden before the commercial possibilities of the region can be appraised adequately.

One method to obtain a detailed knowledge of the area may be suggested. First, an accurate topographic map of the area on a large scale, with perhaps a 2-foot contour interval, should be made. Then a net of bore holes should be placed at some convenient interval, say 500 feet apart, to determine the quality and thickness of the clay bed, as well as the amount of overburden. After this, if necessary, drill holes can be placed closer together for greater detail on the true value of the deposit locally. This procedure, or any other systematic plan whereby the necessary data can be obtained, should be carried out as the first step toward exploitation.

FLINT RIVER FORMATION

An area in Holmes, Jackson, and Washington Counties, mapped as Glendon formation by Cooke and Mosson [75] is now thought to be younger than the typical Glendon of Alabama and has been renamed Flint River formation.[76] According to Cooke and Mossom,[77]

> The unweathered part of the Glendon [Flint River] formation consists of hard cream-colored, yellowish, or pinkish limestone. It is generally more or less porous and, like the Ocala, is composed largely of the remains of marine organisms. Where the limestone has long been exposed to the weather part or all of its soluble portion has been removed and the insoluble residue has been more or less distorted by settling. Lumps of silicified limestone or chert, commonly containing casts and molds of fossil shells, are embedded, in red, white, purple, or mottled residual clay. * * * Where fossiliferous cherts are absent the residual clay of the Glendon [Flint River] formation can usually be distinguished from primary clays of other formations by the distortion of its beds.

In this area a large amount of residual clay has been derived from the Flint River formation, and deposits of activable clays are also associated with the formation. Tests of clay samples taken from the

[75] Cooke, C. W., and Mossom, Stuart, op. cit., pl. 2.
[76] Cooke, C. W., Am. Assoc. Petroleum Geologists Bull., vol. 19, p. 1170, August 1935.
[77] Florida Geol. Survey 20th Ann. Rept., pp. 67–69, 1929.

stations described below illustrate the bleaching quality of some of these clays.

An exposure at station 27, southeast of Chipley, in Washington County, shows the following section:

	Feet
2. Sand, gray and brown, mottled	20
1. Clay, greenish gray, mottled red, irregularly bedded, waxy, sandy (3 samples)	8

The tests of three samples from the clay outcrop indicate that the material is activable and may prove valuable as a high-grade bleaching agent. Additional information should be obtained regarding the extent and the bleaching quality of the clay at other points.

Station 28, 5.7 miles west of Cottondale on United States Highway 90, is included for the purpose of locating a number of auger samples obtained at this point by F. C. Westendick of the Florida Geological Survey. Herman Gunter, State geologist, submitted the samples for testing to the Federal Geological Survey. The section is as follows:

	Feet
Top of boring.	
4. Sand, dull gray, very fine-grained, clayey	9
3. Clay, greenish gray, waxy, silty (2 samples)	10
2. Sand, yellowish, fine-grained, clayey	4
1. Clay, greenish gray, mottled brown, very waxy, silty, but becoming sandy at base (3 samples)	18

As shown in the tables, the clay has a high bleaching power after acid treatment, as well as raw. Its thickness and quality recommend it for further study.

At station 29, in the SW¼ sec. 22, T. 4 N., R. 10 W., on a north-south county road, the following section is exposed:

	Feet
3. Soil, brown, sandy	1
2. Sand, gray and brown mottled, medium-grained	4
1. Clay, gray, mottled brown, waxy, sandy, basal portion containing sand laminae (3 samples)	9

The oil bleach ratings for three samples taken from the exposure and by hand auger indicate an activable clay close to the lower limit for commercial use. The bleach ratings are sufficiently high to warrant additional study, and the tests on the raw clay indicate a good quality of fuller's earth.

MIOCENE DEPOSITS

As identified by Cooke and Mossom,[78] the Miocene of Florida is divided into the following formations: Tampa limestone at the base; Alum Bluff group, consisting of the Hawthorn formation and contemporaneous Chipola formation, the Oak Grove sand, and the Shoal

[78] Cooke, C. W., and Mossom, Stuart, op. cit., p. 77.

River formation; and Choctawhatchee formation at the top. Only clays of the Tampa and the Hawthorn formations were studied during this investigation.

TAMPA LIMESTONE

The Tampa formation has been described [79] as consisting almost entirely of limestone varying from a pure-white or greenish to a creamy-yellow color. The upper part of the formation contains siliceous residual material and at many places much fine sand. There are also pockets of greenish clay throughout the limestone, as well as deposits of residual clay at the more weathered points.

The present investigation shows the presence of activable clays in the Tampa formation. Of the few outcrop samples, only one is of importance.

At an exposure 0.8 mile south of Alford, Jackson County, in a cut of the Atlanta & St. Andrews Bay Railroad (station 32), the following section was measured:

	Feet
4. Soil, dark brown	1
3. Clay, greenish gray, waxy, sandy	6
2. Sand, gray, fine-grained, clayey (2 samples)	3
1. Clay, greenish gray. red in spots, waxy, sandy, merges imperceptibly into sand at base (3 samples)	6

Analyses of the samples from this locality indicate a fairly high grade activable clay bed, well worth additional study. If the deposit is found to be commercially valuable, transportation is easily available on the Atlanta & St. Andrews Bay Railroad, as the bed is exposed in a cut on the main line. This place lies near the contact of the Vicksburg and Tampa formations as mapped by Cooke and Mossom. The deposit may form part of the Flint River formation rather than the Tampa limestone, to which it is here referred. The samples collected by Mr. Bay from this locality are described on page 305.

HAWTHORN FORMATION

A description of the Hawthorn formation and of the fuller's earth deposits now being mined in it will be found in the preceding paper by H. X. Bay (pages 307–317) as well as in other publications. Tests of samples from the Hawthorn, listed in the tables, seem to indicate that much excellent activable clay is present in this formation in Florida.

At station 35, in Gadsden County, 5.0 miles east of Quincy on United States Highway 90, the following section in a highway cut on the east side of Little River was measured:

[79] Idem, p. 79.

	Ft.	in.
7. Sand and clay, light gray, interbedded and crossbedded	35	0
6. Clay, light greenish gray, waxy (sampled)	2	0
5. Sand, light gray, hard, micaceous	1	4
4. Clay, gray, waxy, manganese stain (sampled)	2	0
3. Clay, gray, very waxy (sampled)	2	0
2. Sand and clay, gray, alternating in thin laminae	1	0
1. Sand, light gray, medium-grained, thin-bedded	5	0

As shown in the tables, three samples were taken, one each from beds 6, 4, and 3. The bleach ratings for these samples are not quite up to the minimum requirements for activable clay, but this may be due to weathering on the outcrop. Perhaps fresh samples would show a somewhat better test. To judge from this 200-foot exposure along the road, the clay beds seem persistent and fairly constant. The locality is well worth further exploration.

In Leon County, in the vicinity of Tallahassee, several outcrops were examined. Bleaching tests of samples from these localities point to a considerable deposit of high-grade material.

Station 38, on United States Highway 19, 4.9 miles southeast of the State capitol in Tallahassee, shows the following section:

	Feet
2. Sand, brownish, coarse-grained	10
1. Clay, gray, mottled tan, waxy, sandy (sampled)	2

A single sample, obtained from the middle of the clay outcrop, showed a high bleach rating after acid treatment. As the exposure was not drilled, the total thickness of the bed is unknown. Further work is strongly recommended at this and nearby points.

The following section was measured at station 39, an exposure on the Meridian road, 4.8 miles north of the State capitol:

	Feet
2. Sand, red, coarse-grained	10
1. Clay, light gray and tan, very waxy, gritty (2 samples)	3

The two samples taken both show excellent bleaching quality, with good color separation after acid treatment.

Station 40, on the Meridian road 0.95 mile north of station 39, is undoubtedly an outcrop of the same bed. The two sections are very similar, as are the results of the tests.

	Feet
2. Sand, red, coarse-grained	10
1. Clay, light gray and tan, very waxy, gritty (2 samples)	4

As indicated, the two samples tested have good bleaching power.

At an outcrop 0.1 mile north of Meridian (station 41) on the road to Beachton, Ga., the following section was measured:

	Feet
3. Clay, gray, mottled dark brown, badly weathered	1
2. Sand, gray, coarse-grained	10
1. Clay, mottled gray and tan, waxy, sandy (sampled)	2

A sample from bed 1 shows a bleaching power not quite up to minimum requirements but indicates the presence of activable clay, which should be studied in more detail.

Station 42, 4.4 miles east of the Meridian road, on a county road that intersects it 17.2 miles north of the State capitol, shows the following section:

	Feet
3. Soil, brown, sandy	1
2. Sand, brownish red, coarse-grained	5
1. Clay, gray, mottled brown, waxy, sandy (sampled)	2

The sample from this station gave a bleaching test which indicates a high-grade material. The thickness of the bed is not known, as the base is not exposed.

Another outcrop of the same bed occurs at station 43, on the same road 0.8 mile east of station 42. This exposure was not sampled but should be noted for future examinations in the area. The clay bed is 5 feet thick here, with a 4-foot overburden of sand.

At station 44, in Jefferson County on Florida Highway 11, 6.7 miles north of United States Highway 19, the following section is exposed:

	Feet
2. Sand, gray, medium-grained	5
1. Clay, gray, mottled brown, waxy, sandy (sampled)	2

One sample from the middle of the clay exposed gave a very high bleach rating after activation. The total thickness of the bed is unknown, but the locality is recommended, not only because of the high quality of the bleaching clay, but also because of its proximity to the Seaboard Air Line Railway, which is about a quarter of a mile south of the outcrop.

Station 45 is in Jefferson County, on Florida Highway 11, 15 miles north of the courthouse in Monticello, where the following section is exposed:

	Feet
2. Sand, brownish red, coarse-grained	4
1. Clay, gray, mottled brown, waxy, sandy (2 samples)	4

Of two samples taken from this clay exposure, the top one gave an excellent bleach rating after activation, though the lower one did not. The road cut shows that the clay bed is very irregular, thickening and thinning greatly within short distances. Because of this, the value of the clay deposit is questionable, but it seems worthy of additional study.

The following section is exposed at station 46, on Florida Highway 11, 0.8 mile north of station 45:

	Feet	in.
2. Soil, brown, sandy	0	6
1. Clay, gray, mottled brown, waxy, sandy	3	0

This clay was not sampled, but it appears to be a continuation of the bed observed at station 45. Approximate measurements with a hand level indicate that station 46 is about 30 feet, topographically, above station 45. As at the preceding location, the bed is very irregular and its value doubtful.

An exposure at station 47, on Florida Highway 11, 5.1 miles north of the courthouse in Monticello, or 2.8 miles north of station 46, shows the following section:

	Feet
3. Sand, red, coarse grained, cross-bedded	10
2. Clay, gray and tan, very evenly bedded, waxy, sandy (3 samples)	6
1. Sand, gray, coarse-grained	(?)

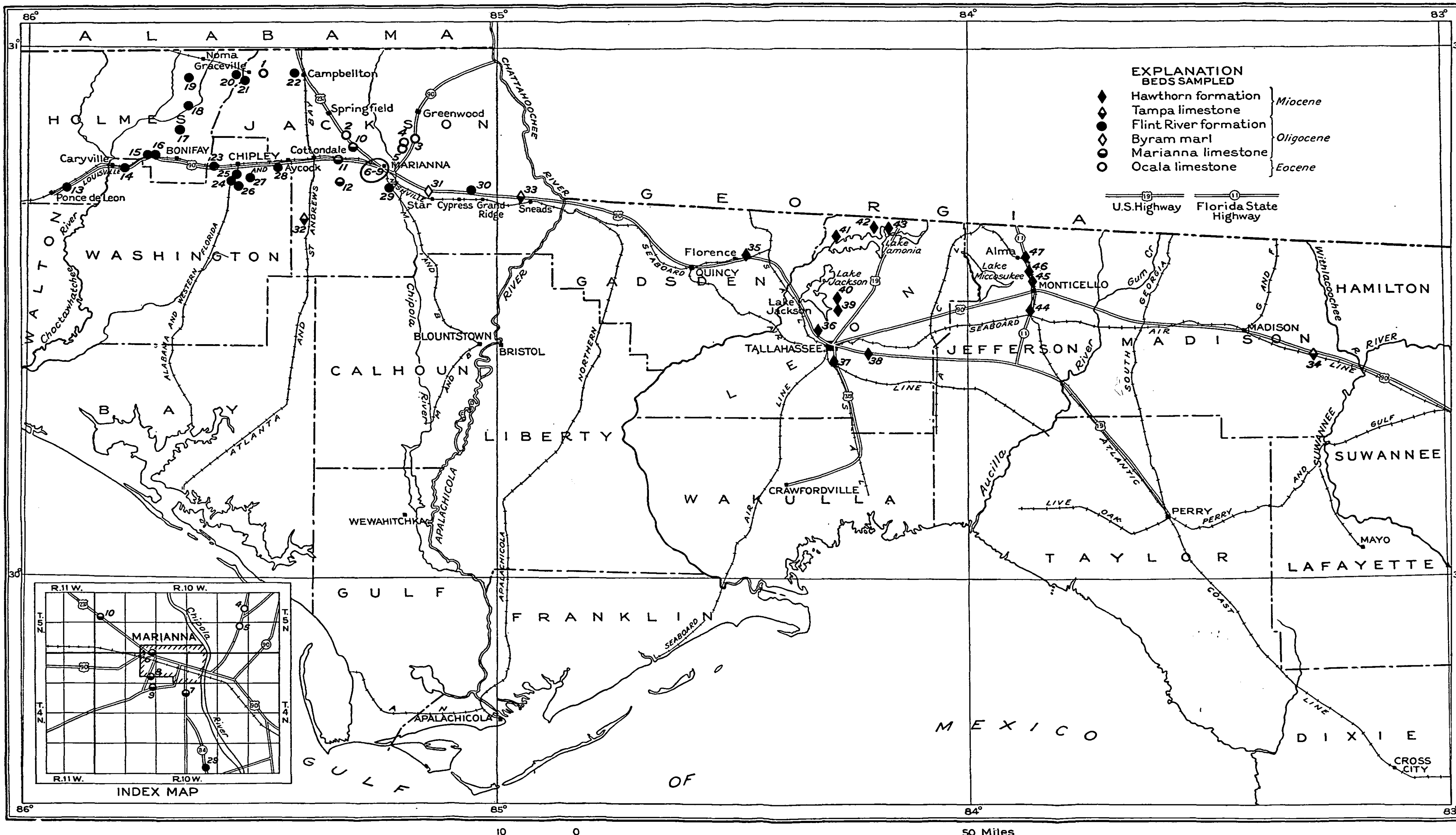
The clay bed at this point dips about 5° N. As shown in the tables, three samples from the bed were activable but were not quite up to the minimum requirements.

SUMMARY AND TABULATION OF RESULTS

Deposits at the locations discussed above are considered most likely to be of commercial interest, chiefly because of their excellent response to bleaching tests. Little attempt was made in the field to delimit deposits except to make tentative correlations in small areas. Consequently, the quality of a bed as a whole should not be judged from the information obtained from a few scattered exposures. A program of intensive drilling and sampling should be undertaken to determine the potentialities of a given area, as the initial step in development.

Several areas are considered worthy of additional investigation in more detail. These are (1) the Marianna district; (2) the vicinity of station 28, 5.7 miles west of Cottondale on United States Highway 90, in Washington County; (3) the area south and southeast of Chipley, in Washington County; (4) the region in the vicinity of Alford, in Jackson County; (5) the area surrounding Tallahassee, in Leon County; and (6) the region about Monticello, in Jefferson County.

Additional areas that possibly deserve attention can be selected from the tables that follow.



MAP OF PART OF FLORIDA SHOWING LOCALITIES TESTED.

Bleach rating of clay samples from Florida

Eocene clays

Station No.	Location	Description of bed		Position of sample in bed	Oil bleach								Acid-soluble			
		Character	Thickness		Raw				Acid-treated				Fe	Al	Ca	Off (per-cent)
			Ft. in.		G	Y	R	B	G	Y	R	B				
1	Jackson County; State Highway 123, 5.3 miles west of United States Highway 231, in Campbellton, ditch on north side of road.	Gray, mottled brown and red, waxy, very sandy, badly weathered.	3 6	Middle 1 foot	0.8	0.9	1.0	1.2	1.1	1.7	2.0	2.2	5	5	0	25
2	Jackson County; United States Highway 231, 5½ miles northwest of courthouse in Marianna, cut on northeast side of road.	Grayish yellow, somewhat greasy and gritty. (May be Oligocene.)	3 0	Composite	.5	.5	.5	.5	1.2	1.5	1.7	2.5	Tr.	Tr.	10	75
3	Jackson County; State Highway 90, 4 miles northeast of courthouse in Marianna, ditch on west side; auger samples, except first.	Gray, waxy, sandy	8 8	Top 1 foot	.8	.9	1.0	1.0	1.0	1.2	1.4	1.7	1	9	0	20
				5 feet below top	.6	.7	.8	.9	.9	1.1	1.3	1.6	1	9	0	20
				7.3 feet below top	.6	.7	.8	.8	1.2	1.5	1.7	2.0	1	9	0	15
4	Jackson County; SE½ sec. 26, T. 5 N., R. 10 W., on north-south county road, west side.	Gray, mottled brown, massive, waxy, sandy.	6 0	Top 1 foot	.7	.8	.8	.8	1.1	1.4	1.6	1.9	6	4	0	25
				Middle 1 foot	.6	.7	.8	.9	1.1	1.4	1.6	1.9	6	4	0	25
				Basal 1 foot	.4	.5	.6	.6	.9	1.2	1.4	1.7	6	4	0	25
		Gray, brown streaks, sandy	3 6	1.3 feet below top	.7	.8	.9	.9	.9	1.2	1.4	1.6	6	4	0	25
		Mostly gray with a little brown, waxy, sandy.	1 0	Top of bed	.7	.8	.9	1.0	.7	.9	1.1	1.3	6	4	0	25
5	Jackson County; NE¼ sec. 35, T. 5. N., T. 10 W., on north-south county road.	Gray, mottled brown, laminated, waxy, sandy, very smooth texture.	2 0	Composite	.6	.7	.8	.9	.7	.9	1.0	1.1	2	8	0	20

Bleach rating of clay samples from Florida—Continued

Oligocene clays

Station No.	Location	Description of bed: Character	Description of bed: Thickness	Position of sample in bed	Oil bleach: Raw G	Raw Y	Raw R	Raw B	Oil bleach: Acid-treated G	Acid-treated Y	Acid-treated R	Acid-treated B	Acid-soluble: Fe	Al	Ca	Oil (per-cent)
			Ft. in.													
6	Jackson County; United States Highways 231 and 90, junction at northwest edge of Marianna, road cut on northeast side; auger samples except first.	Gray, mottled red, waxy, gritty	2 0	Top 1 foot	1.1	1.2	1.2	1.3	1.2	1.5	1.7	1.8	5	5	0	20
		Gray, mottled red, waxy, gritty	3 0	1.3 feet below top	1.1	1.2	1.3	1.5	1.0	1.8	2.3	2.5	6	4	Tr.	25
				1.8 feet below top	1.2	1.5	1.7	1.9	1.2	2.2	2.7	3.2	5	5	Tr.	30
				2.5 feet below top	1.1	1.2	1.2	1.2	1.1	2.1	2.9	3.6	5	4	1	30
		Red and yellow waxy, gritty	3 5	3 feet below top	1.1	1.2	1.2	1.2	1.1	1.9	2.6	3.7	5	4	1	30
				Base of bed	1.0	1.4	1.6	1.8	1.2	1.8	2.5	3.0	5	5	0	25
		Brick red, gray patches, waxy, gritty	4 10	3 feet below top	1.1	1.4	1.7	2.0	1.3	1.9	2.4	3.6	5	4	1	30
				Base of bed	.8	1.0	1.1	1.2	1.1	1.7	2.1	2.6	5	5	Tr.	25
		Light green, waxy, containing limestone particles, Marianna (?) limestone at base.	2 0	Composite	.7	.8	.8	.9	1.2	1.7	2.2	2.7	5	4	1	25
7	Jackson County; line road between secs. 9 and 10, T. 4. N., R. 10 W., 0.9 mile south of courthouse in Marianna.	Gray, mottled brown, irregularly bedded, waxy and greasy, sandy.	15 0	Top 1 foot	.9	1.2	1.4	1.8	1.0	1.4	1.6	2.0	5	5	0	25
				Middle 1 foot	1.2	1.5	1.6	1.7	1.1	1.9	2.4	3.5	5	5	0	25
				Basal 1 foot	1.2	1.6	1.8	1.8	1.2	1.7	2.1	2.6	5	5	Tr.	25
8	Jackson County; 1.9 miles southwest of courthouse in Marianna on Kynesville road to north-south county road, thence 0.5 mile north. Lower 3 samples from auger hole.	Gray, mottled red, waxy, sandy; basal 4 feet contains more sand than clay.	25 0	Top 1 foot	1.1	1.2	1.3	1.4	.8	1.0	1.2	1.4	2	8	0	30
				3 feet below top	.8	.9	1.0	1.0	1.1	1.3	1.5	1.7	3	7	0	25
				6 feet below top	1.0	1.1	1.2	1.3	1.1	1.3	1.6	2.0	2	8	0	25
				16 feet below top	.9	1.1	1.3	1.4	1.1	1.3	1.7	2.1	4	6	0	25
				19.5 feet below top	.8	1.0	1.1	1.3	.7	1.1	1.4	1.8	3	7	0	25
		Ochreous, waxy, very sandy at top; 1 foot iron crusts in middle; 1.4 feet green limy clay at base.	4 5	1 foot below top	1.0	1.2	1.3	1.4	1.0	1.5	1.9	2.2	2	8	0	25
9	Jackson County; 1.7 miles southwest of courthouse in Marianna on Kynesville road, cut; *all but first two* are auger samples.	Gray, mottled brownish, and red, waxy, sandy.	6 0	Top 1 foot	1.2	1.4	1.5	1.6	1.1	1.8	2.2	2.7	4	6	0	25
				3 feet below top	1.0	1.1	1.1	1.1	1.1	1.6	1.9	2.7	4	6	0	30
		Greenish gray, waxy, sandy streaks	4 6	Top of bed	1.1	1.2	1.2	1.2	1.2	1.9	2.3	2.8	4	6	0	30
				1.6 feet below top	1.2	1.4	1.5	1.6	1.1	2.0	2.1	2.1	3	7	0	25
				3.5 feet below top	1.3	1.6	1.8	2.0	1.2	2.2	2.8	3.1	6	4	0	30

		Brown, ochreous, waxy, sandy, much manganese.	7	6	1.4 feet below top	1.2	1.4	1.5	1.5	1.0	1.9	2.5	2.6	5	5	0	30
10	Jackson County; U. S. Highway 231, 3.4 miles northwest of courthouse in Marianna.	Light gray, irregularly laminated, waxy, a a little gritty, fossils.	3	0	Composite	.3	.4	.4	.4	.9	1.5	2.0	2.2	Tr.	Tr.	10	65
		Greenish gray, waxy, gritty, fossils	1	0	do	.2	.3	.3	.3	.6	1.2	1.4	1.7	Tr.	Tr.	10	60
11	Jackson County; U. S. Highway 90, 4.6 miles west of courthouse in Marianna; auger samples.	Light gray, streaked red, waxy, sandy; basal 1 feet contains sand laminae.	6	6	5 feet below top	1.0	1.1	1.2	1.3	1.3	2.0	2.2	2.8	1	9	0	25
		Greenish gray, waxy, sand streaks	4	0	Top of bed	.5	.6	.6	.6	.9	1.6	1.8	2.2	5	5	0	25
		Green at top, gray at base, waxy, gritty; ¼-inch limestone layer near middle.	1	10	0.9 foot below top	.3	.4	.4	.4	1.3	1.8	2.2	2.6	5	4	1	30
		Light gray, waxy; much sand, coarse	2	6	Top of bed	.7	1.0	1.1	1.1	1.2	1.6	1.8	2.2	3	7	Tr.	25
		Light gray, waxy, sandy; small sand streaks.	2	4	do	.9	1.0	1.1	1.2	1.2	1.6	1.8	2.5	1	9	Tr.	25
12	Jackson County; 7 miles west of courthouse in Marianna on Kynesville road; auger samples except first.	Greenish gray, waxy, gritty	2	0	Composite	.9	1.1	1.2	1.2	1.0	1.3	1.5	1.9	6	4	0	30
		Greenish gray, mottled red, gritty; upper 5 inches sand.	4	4	1.3 feet below top	1.4	1.5	1.6	1.6	1.4	2.3	3.1	4.0	5	5	Tr.	25
					2.5 feet below top	1.2	1.4	1.5	1.7	1.4	2.0	2.8	3.7	6	4	0	30
		Brown and gray, sandy at top only; some manganese stains.	3	5	Top of bed	1.1	1.3	1.4	1.6	1.0	1.5	1.8	2.4	5	5	0	25
					2 feet below top	.9	1.1	1.2	1.3	1.2	1.9	2.6	3.3	5	5	Tr.	30
					Base of bed	1.1	1.3	1.4	1.4	1.1	1.8	2.3	3.3	5	4	1	30
13	Holmes County; U. S. Highway 90, 1.7 miles northeast of Ponce de Leon; lower sample from boring.	Gray, mottled brown, waxy, sandy	3	0	Top 1 foot	.8	.9	1.0	1.0	.8	1.1	1.2	1.5	5	5	0	25
					3 feet below top	.9	1.0	1.1	1.1	.9	1.2	1.4	1.7	5	5	0	30
14	Washington County; U. S. Highway 90, 6.1 miles southwest of Bonifay Main Street; lower sample from boring.	Gray, mottled brown, waxy, very sandy	4	0	2 feet below top	.9	1.1	1.3	1.5	1.1	1.5	1.8	2.2	5	5	0	20
					4 feet below top	1.0	1.2	1.3	1.5	1.2	1.7	2.0	2.4	4	6	0	20
15	Holmes County; U. S. Highway 90, 2.9 miles west of Bonifay Main Street; last 3 are auger samples.	Gray, mottled brown, waxy, gritty	7	0	Top 1 foot	.9	1.1	1.2	1.4	.8	1.1	1.4	1.8	5	5	0	25
					4 feet below top	.8	1.0	1.1	1.3	.7	1.1	1.4	1.6	4	6	Tr.	20
					5.5 feet below top	.6	.8	.9	1.1	.8	.9	.9	.9	3	7	0	25
		Gray, mottled purple, waxy, sandy	3	0	Top of bed	1.0	1.1	1.2	1.3	.7	1.0	1.2	1.6	2	8	0	25
					Base of bed	.6	.8	.9	1.1	.7	.8	1.1	1.6	1	9	0	25
16	Holmes County, U. S. Highway 90, 1.85 miles west of Bonifay Main Street, road cut.	Gray, mottled brown, waxy, sandy	3	0	Composite	1.0	1.2	1.3	1.5	1.0	1.3	1.5	1.8	5	5	0	25
		Gray, mottled brown, not waxy or greasy, gritty.	6	0	do	.8	1.0	1.1	1.1	1.1	1.3	1.4	1.9	4	6	0	25

Bleach rating of clay samples from Florida—Continued

Oligocene clays—Continued

Station No.	Location	Description of bed: Character	Thickness	Position of sample in bed	Oil bleach: Raw G	Raw Y	Raw R	Raw B	Acid-treated G	Acid-treated Y	Acid-treated R	Acid-treated B	Acid-soluble: Fe	Al	Ca	Off (percent)
			Ft. in.													
17	Holmes County; State Highway 39, 3.5 miles north of U. S. Highway 90 in Bonifay.	Gray, mottled brown, waxy, gritty at top, grading into sand at base.	2 0	Middle	.7	.9	.9	1.0	.7	.9	1.1	1.2	4	6	0	20
18	Holmes County; State Highway 39, 6.5 miles north of U. S. Highway in Bonifay; lower sample from boring.	Gray, mottled purple, waxy, sandy	6 0	2 feet below top 5.6 feet below top	.7 .8	.9 1.0	1.0 1.1	1.1 1.2	.9 .9	1.1 1.1	1.4 1.2	1.7 1.5	5 5	5 5	0 0	25 25
19	Holmes County; State Highway 39, northern part of line between secs. 8 and 9, T. 6 N., R. 14 W.; auger samples except first.	Gray, mottled, brown, waxy, sandy	9 0	2 feet below top 5 feet below top 7 feet below top	.8 .8 .7	.9 1.0 .8	1.1 1.1 .9	1.1 1.2 1.0	.8 .6 1.0	.9 .8 1.2	1.0 .9 1.3	1.0 1.0 1.6	4 6 4	6 4 6	0 0 0	20 20 20
		Gray and tan, very waxy	1 0	0.7 feet below top	.7	.9	1.0	1.1	.9	1.1	1.2	1.5	6	4	0	25
20	Holmes County; State Highway 165, 2.4 miles west of Graceville; lower sample from boring.	Gray, mottled brown, waxy, sandy, lenticular deposit.	4 0	1 foot below top 4 feet below top	.8 .7	.9 .9	1.0 1.0	1.1 1.1	1.0 .6	1.3 .7	1.4 .7	1.5 .8	5 4	5 6	0 0	20 20
21	Jackson County; State Highway 52, 11.1 miles north of U. S. Highway 90 in Chipley.	Gray, mottled brown, waxy, very sandy	2 0	Composite	.6	.8	.9	1.0	.8	1.3	1.7	2.0	4	6	0	25
22	Jackson County; State Highway 123, 1.2 miles west of U. S. Highway 231 in Campbellton; lower sample from boring.	Gray, mottled brown, waxy, sandy	5 8	1.5 feet below top 4.8 feet below top	.7 .8	.8 .9	1.0 1.0	1.1 1.2	1.1 1.1	1.5 1.4	1.7 1.6	2.0 1.9	6 4	4 6	0 0	25 20
23	Washington County; U. S. Highway 90, 3 miles west of courthouse in Chipley; last two are auger samples.	Medium gray, mottled brown, red, and purple, waxy, somewhat gritty.	8 6	Top 1 foot 3.5 feet below top 7 feet below top	.7 .8 .5	.8 1.1 .7	.9 1.1 .7	1.0 1.2 .8	1.0 1.1 .9	1.3 1.3 1.1	1.5 1.5 1.3	1.8 1.8 1.6	3 1 1	7 9 9	0 0 0	25 20 25
		Dark gray, mottled purple, waxy, gritty	1 0	Top of bed	.8	1.1	1.2	1.3	1.2	1.3	1.4	1.6	1	9	0	20
		Purple, streaked gray, waxy, sandy	8	Base of bed	.7	.8	.9	1.0	.9	1.1	1.2	1.4	3	7	0	20
24	Washington County; State Highway 52, 2.2 miles south of U. S. Highway 90 in Chipley; lower two samples from boring.	Steel gray, mottled purple, a little waxy, very sandy; grades into sand at base.	6 4	1.5 feet below top 4.4 feet below top 6.3 feet below top	1.0 .9 .7	1.3 1.1 .9	1.5 1.2 1.0	1.6 1.4 1.2	.8 1.1 .9	1.1 1.4 1.1	1.6 1.5 1.2	1.7 2.0 1.6	5 5 5	5 5 5	0 0 0	25 25 25

25	Washington County; NE ¼ sec. 16, T. 4 N., R. 13 W., on north-south county road.	Greenish gray, mottled brown, waxy, very sandy.	3	0	Composite	1.1	1.4	1.6	1.8	1.2	1.6	2.0	2.7	5	5	0	30
26	Washington County; SW ¼ sec. 21, T. 4 N., R. 13 W., on north-south county road.	Gray, mottled red, somewhat waxy, very sandy.	3	0	do	1.1	1.4	1.6	1.8	1.1	1.5	2.0	2.5	3	7	0	25
27	Washington County; west center sec. 14, T. 4 N., R. 13 W., on county road.	Greenish gray, mottled red, waxy, sandy	8	0	Top 1 foot	1.5	1.5	1.5	1.5	1.1	1.8	2.7	3.4	5	5	Tr.	30
					Middle 1 foot	.6	.7	.7	.7	1.5	2.1	2.5	2.7	6	4	0	30
					Basal 1 foot	.3	.4	.4	.4	1.3	1.7	2.2	3.0	5	4	1	30
28	Washington County; U. S. Highway 90, 5.7 miles west of Cottondale, 900 feet south of road, at well of Earthine Co.; all auger samples.	Greenish gray, silty, middle greenish gray, very gritty; lower 4 feet (not sampled) gray sand.	10	0	Top 1 foot	1.0	1.2	1.3	1.5	1.2	2.0	2.5	3.1	3	7	Tr.	25
					Middle 1 foot	.9	1.0	1.1	1.2	1.1	1.7	2.2	2.9	2	8	0	25
		Greenish gray, mottled brown, waxy	18	0	Top 1 foot	1.2	1.3	1.4	1.4	1.1	2.0	2.9	3.8	5	5	Tr.	25
					7 feet below top	1.1	1.3	1.4	1.5	1.2	2.1	3.0	4.0	4	5	1	30
					Basal 1 foot	.9	1.0	1.0	1.0	1.1	1.7	2.6	3.3	5	4	1	30
29	Jackson County; SE ¼ sec. 22, T. 4 N., R. 10 W., on north-south county road; lower 2 samples from boring.	Gray, mottled brown, waxy, sandy, basal portion consists of alternating sand and clay beds 2 to 3 inches thick.	9	0	Top 1 foot	1.2	1.5	1.7	1.9	1.1	1.8	2.5	3.6	4	6	0	30
					6 feet below top	.9	1.2	1.4	1.5	1.0	1.8	2.0	2.5	5	5	0	30
					9 feet below top	1.1	1.4	1.5	1.6	1.0	1.8	2.2	2.8	5	5	0	25
30	Jackson County; U. S. Highway 90, 11.2 miles east of courthouse in Marianna; All auger samples except first.	Brown, mottled red, waxy, sandy	6	0	Composite of top 2 feet.	.6	.8	.9	1.0	1.0	1.2	1.3	1.5	6	4	0	30
					4 feet below top	.6	.7	.9	1.2	.9	1.2	1.3	1.5	6	4	0	30
					6 feet below top	1.0	1.1	1.2	1.3	1.0	1.3	1.5	1.9	5	5	0	20
		Dark red, waxy, sandy	1	0	0.5 foot below top	1.1	1.2	1.3	1.4	1.1	1.3	1.4	1.6	5	5	0	20
31	Jackson County; U. S. Highway 90, 6.9 miles east of courthouse in Marianna; auger samples except first.	Gray, mottled pink, waxy, sandy. (May be of Byram age.)	1	0	Top 1 foot	.6	.7	.8	.9	.8	1.0	1.1	1.2	5	5	0	15
		Gray, mottled purple, waxy, sandy	8	0	4.5 feet below top	.7	.9	1.0	1.1	.9	1.2	1.3	1.4	3	7	0	25
					Basal 2 feet	.5	.6	.7	.7	.9	1.1	1.2	1.2	5	5	0	20
		Miocene clays															
32	Jackson County; State Highway 20, 0.8 mile south of Alford, in cut of Atlanta & St. Andrews Bay R. R. (Same as Bay locality, p. 305.)	Greenish gray, laminated, waxy, sandy	6	0	Top 1 foot	1.1	1.4	1.5	1.5	.8	1.5	2.1	2.9	5	5	0	30
					Basal 1 foot	.7	.8	.8	.8	1.1	1.8	2.4	3.5	5	5	0	30
		Greenish gray, laminated, waxy, sandy, basal 1 foot is auger sample.	5	0	Top 1 foot	.7	.8	.8	.8	1.0	2.0	2.3	2.7	4	5	1	25
					Middle 1 foot	.6	.7	.7	.7	1.6	2.5	2.6	2.6	5	5	Tr.	25
					Basal 1 foot	.6	.7	.7	.7	1.2	2.0	2.1	2.2	5	4	1	25
33	Jackson County; U. S. Highway 90, 1.5 miles west of Sneads.	Gray, waxy, sandy, much manganese	5	0	Basal 2 feet	.8	1.1	1.2	1.3	.6	.9	1.1	1.3	4	6	0	25

Bleach rating of clay samples from Florida—Continued

Miocene clays—Continued

Station No.	Location	Description of bed			Position of sample in bed	Oil bleach								Acid-soluble			
		Character	Thickness			Raw				Acid-treated				Fe	Al	Ca	Off (per-cent)
			Ft.	in.		G	Y	R	B	G	Y	R	B				
34	Madison County; U. S. Highway 90, 11 miles east of courthouse in Madison, 300 feet north of road.	Grayish white, waxy, sandy, granular	15	0	Middle 1 foot	.7	.8	.8	.8	1.0	1.3	1.6	2.0	0	9	1	45
35	Gadsden County; U. S. Highway 90, 5 miles east of Quincy, cut on east hill down to Little River.	Light greenish gray, waxy, gritty, basal 4 inches sand.	2	4	Composite	.2	.3	.3	.3	.8	1.3	1.9	2.9	5	5	Tr.	25
		Gray, waxy, much manganese	2	0	do	.6	.7	.7	.7	.8	1.3	1.8	2.8	5	5	Tr.	30
		Gray, waxy	2	0	do	.1	.2	.2	.2	.8	1.4	1.9	2.6	5	5	Tr.	25
36	Leon County; old Quincy road, 3 miles northeast of Tallahassee city limit.	Gray, mottled tan, waxy and greasy, not gritty.	8	0	Top 1 foot	.2	.3	.3	.3	1.1	1.3	1.4	1.6	4	6	Tr.	25
					Middle 1 foot	.3	.4	.4	.4	1.3	2.3	2.4	2.5	5	5	Tr.	30
					Basal 1 foot	.3	.4	.4	.4	1.2	2.2	2.3	2.3	5	4	.1	30
37	Leon County; U. S. Highway 319, 1.3 miles south of State capitol in Tallahassee.	Gray, waxy, a little gritty, bedded but lenticular.	10	0	Top 1 foot	.6	.7	.7	.7	1.1	1.6	2.1	2.8	5	5	0	35
					Middle 1 foot	.2	.3	.3	.3	1.2	2.1	2.2	2.2	5	5	0	25
					Basal 1 foot	.2	.3	.3	.3	1.2	2.1	2.2	2.3	5	5	0	30
38	Leon County; U. S. Highway 19, 4.9 miles southeast of State capitol in Tallahassee.	Gray, mottled tan, waxy, sandy	2	0	Middle 1 foot	1.0	1.1	1.1	1.1	1.1	1.9	2.5	3.2	5	5	0	30
39	Leon County; Meridian road, 4.8 miles north of State capitol in Tallahassee.	Gray, mottled tan, very waxy, gritty	3	0	Top 1 foot	.5	.6	.6	.6	1.1	1.9	2.7	3.4	5	5	0	30
					Basal 1 foot	.3	.4	.4	.5	1.1	1.7	2.3	3.2	5	5	0	30
40	Leon County; Meridian road, 0.95 mile north of station 39.	Gray, mottled tan, very waxy, gritty	4	0	Top 1 foot	.5	.6	.6	.6	1.1	1.8	2.4	3.4	5	5	Tr.	25
					Basal 1 foot	.5	.6	.6	.6	1.1	1.7	2.3	3.5	4	6	0	25
41	Leon County; Meridian road, 1 mile north of Meridian.	Gray, mottled tan, waxy, sandy	2	0	Middle 1 foot	.7	.8	.9	.9	.8	1.3	1.8	2.7	5	5	0	2
42	Leon County; Meridian road, 17.2 miles north of State capitol in Tallahassee, thence 4.4 miles east on county road.	Gray, mottled brown, waxy, sandy	2	0	Middle 1 foot	.5	.6	.6	.6	1.0	1.4	2.0	3.1	4	6	0	2
43	Leon County; 0.8 mile east of station 42; not sampled.	Gray, mottled brown, waxy, sandy															

44	Jefferson County; State Highway 11, 6.7 miles north of U. S. Highway 19.	Gray, mottled brown, waxy, sandy	2	0	Middle 1 foot	.7	.8	.9	.9	1.3	1.8	2.4	3.3	4	6	0	30
45	Jefferson County; State Highway 11, 1.5 miles north of courthouse in Monticello.	Gray, mottled brown, waxy, sandy	4	0	Top 1 foot	.7	.8	.9	1.0	1.2	2.0	2.7	3.7	5	5	0	25
					Basal 1 foot	.7	.8	.9	1.0	1.1	1.4	1.8	2.4	6	4	0	25
46	Jefferson County; State Highway 11, 0.8 mile north of station 45.	Not sampled; see section on p. 325	----		----	----	----	----	----	----	----	----	----	----	----	----	----
47	Jefferson County; State Highway 11, 5.1 miles north of courthouse in Monticello.	Gray, mottled tan, laminated, waxy, sandy.	6	0	Top 1 foot	.6	.8	.9	1.1	1.1	1.6	2.2	2.5	6	4	0	30
					Middle 1 foot	.5	.6	.7	.7	1.0	1.2	1.8	2.4	4	6	0	30
					Basal 1 foot	.5	.6	.7	.7	1.0	1.2	1.9	2.5	3	7	0	30

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