STATE OF ARKANSAS

Arkansas Resources and Development Commission

Wayne C. Fletcher, Executive Director

DIVISION OF GEOLOGY

Norman F. Williams, Director

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CLAY RESOURCES OF THE WILCOX GROUP IN ARKANSAS

By

Norman F. Williams and Norman Plummer

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STATE OF ARKANSAS

Sid McMath, Governor

Arkansas Resources a[illegible]velopment Commission

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COMMISSIONERS

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ABSTRACT

The beds of the Wilcox group (lower Eocene) outcropping in over 500 square miles of south-central Arkansas have been investigated to determine the occurrence and ceramic properties of the contained clay deposits. On the basis of this preliminary survey and the information consolidated from previous reports, it is evident that excellent white to buff firing clays are contained in lenticular bodies distributed both laterally and vertically through the dominantly sand and silty beds of the Wilcox group in the region. U. S. Bureau of Mines drill records indicate that one such deposit over 60 feet thick contains more than 15 million tons of clay with an average of about 35 per cent alumina. Minable thicknesses of clay were found in 250 test holes and exposures herein described.

Detailed ceramic data collected on 23 new samples and information from previously unpublished ceramic reports on 20 additional samples show wide firing ranges in the white to buff firing clays of the area. As a group these clays show excellent refractory possibilities. P.C.E. determinations reported on 28 samples of clay showed 54 per cent to be low heat duty; 14 per cent to be intermediate heat duty; 14 per cent to be high heat duty and 7 per cent to be super duty refractory clays.

At Malvern, Arkansas, in the west-central part of the area, over 100,000 tons of high grade clay per year is being mined from one deposit. This clay is used in local plants for the production of intermediate and high heat duty refractories and in the manufacture of buff face brick. Although most of this ware is marketed within a few hundred miles a considerable portion is shipped to other parts of the United States and some to Mexico and South America. Comparison of the raw and fired character of this Malvern clay with Tennessee-Kentucky ball clays show them to be essentially the same.

The occurrence of these excellent clays combined with the availability of low priced natural gas, access to rail facilities and a stable source of efficient labor make south-central Arkansas an ideal location for the development of ceramic industries.

CLAY RESOURCES OF THE WILCOX GROUP IN ARKANSAS

By

NORMAN F. WILLIAMS and NORMAN PLUMMER

CHAPTER 1—INTRODUCTION

The purpose of this report is to present all available information on the clay deposits occurring in the outcrop area of the Wilcox group (Eocene) in central Arkansas. In addition to the information resulting from the investigation by the present authors, much material has been included from the unpublished records of the State Mineral Survey and previous reports of the Arkansas Geological Survey.

With the limited time and facilities available, it has not been possible to re-examine all known deposits. Early publication of as much information as could possibly be assembled should best serve the interests of the state by pointing out its almost untouched, potentially valuable clay resources. It is believed that this will serve as an initial step toward the development of a clay industry in the state that will be comparable to that of Tennessee and other adjoining states which are no better favored for clay resources than Arkansas, but where the mining and the sale of clay and clay products is a more important factor in the state's economy.

The early publication of a similar report on the clays of southern Arkansas is contemplated. Additional information on the fired characteristics, mineralogy, and utilization of the present clays is also being collected for later publication. The complete series of these reports will constitute a comprehensive study of the Wilcox clay resources of the state. It is believed that publishing the reports in a series, as the information becomes available, will encourage earlier exploration of the deposits than if a single volume, covering the whole subject, were published at a later date.

PREVIOUS INVESTIGATION

The best published information to date and the only comprehensive work on the clays of the state as a whole is a report by John C. Branner (1908). An earlier report on the geology of Dallas County by Siebenthal (1891) includes excellent description of clay occurrences. Anderson and others (1942) discuss the clay deposits of Saline and Pulaski counties, and the high-alumina clays of these two counties are described in papers by Tracey (1944) and Crockett (1945).

Several field studies have been undertaken and samples collected. Mr. Hugh D. Miser made one such comprehensive study in 1909. These studies were never carried through the testing phase, either due to lack of facilities or funds. Except for a few incomplete reports on Saline and Pulaski County clays, no ceramic data has been published on the clays of this region; the earlier reports confining their data to occurrence and chemical analysis.

LOCATION

The area of this report includes over 550 square miles in parts of Pulaski, Saline, Hot Spring, Grant and Dallas counties and lies immediately southwest of Little Rock in the center of the state (see Fig. 1). The area is served by two lines of the Missouri Pacific railroad and by two lines of the Chicago, Rock Island and Pacific railroad. U. S. Highway 67 follows closely along the northwest border of the area and with several state and county roads serves to make most of the area accessible to motor travel.

METHODS OF INVESTIGATION

During the period 1938-41, a physical inventory of the state's mineral resources was initiated by the State Mineral Survey, financed by the Federal Works Progress Administration, and working under the supervision of the Arkansas Geological Survey* Much effort and expense was involved in this work, but most of the information has never been published. In preparing the present report, all pertinent information from these State Mineral Survey files has been included.

The work of the State Mineral Survey consisted of measuring and sampling beds encountered in shallow auger holes. These holes

* By Act 138 of the General Assembly, 1945, the Arkansas Geological Survey became the Division of Geology, Arkansas Resources and Development Commission.

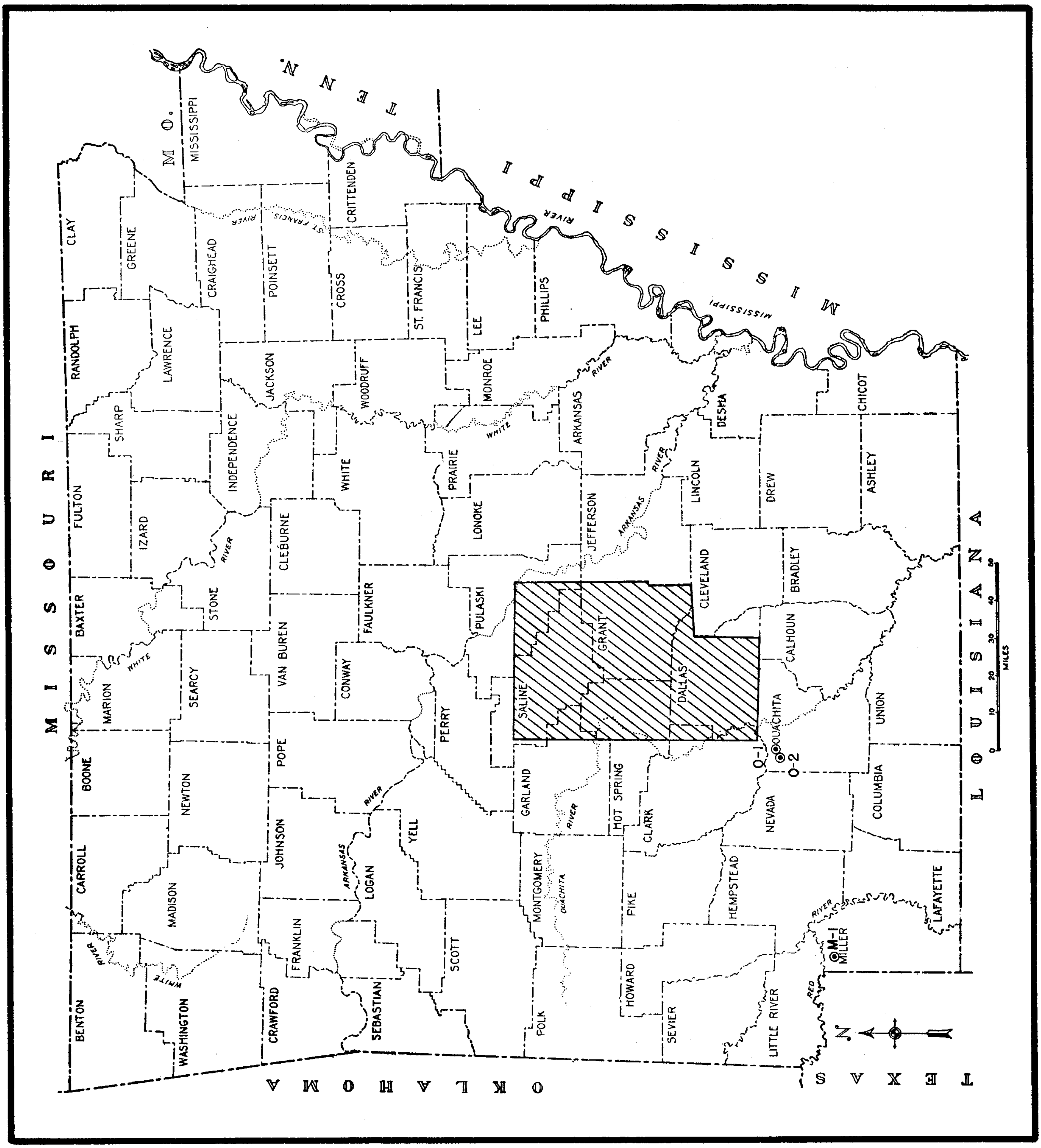


Figure 1. Index Map.

were drilled in nearly every quarter section in the area of outcrop of the Wilcox group. The samples were returned to the organization's laboratory in Little Rock and preliminary tests were made to determine fired characteristics of the material. Promising deposits were test pitted and complete ceramic data obtained from the samples.

In the spring of 1948 the Arkansas Division of Geology began a systematic program of clay investigation in the subject area. Previously reported deposits were plotted on maps and all of those within economic hauling distance of railroads were examined. Any new exposures encountered were also studied. Wherever the thickness and apparent quality of the clay bed were judged to be satisfactory, samples were obtained. Exposures were channeled and covered portions of the deposit were sampled with a 3-inch bucket auger.

The initial examination of these samples was made by a Little Rock ceramic laboratory. Upon completion of the sampling and initial testing the samples were submitted to Mr. Norman Plummer, Ceramist, of the State Geological Survey of Kansas at Lawrence, Kansas. His reports on the characteristics of these clays is included in the description of the deposits (Chapters III to VII). Mr. Plummer also wrote Chapter II.

Six clay samples from Hot Spring, Dallas, and Grant counties were sent to Dr. Victor T. Allen, Head of the Department of Geology, Saint Louis University, who made petrographic studies and wrote the section on mineralogy included in this chapter. Dr. R. E. Grimm did the included X-ray and differential thermal analysis work. Mr. Troy Carney, Division of Geology Chemist, provided analyses of the six clay samples mentioned above.

ACKNOWLEDGMENTS

The cooperation given the Division of Geology by the two brick companies at Malvern is greatly appreciated. Mr. Charles Laird, General Superintendent of the Malvern Brick and Tile Company, allowed the geologists free access to the Company's pit for study and sampling; Mr. D. H. McKellar, Plant Engineer, prepared a report describing the Company's manufacturing procedures, which is included with few modifications in this publication. Mr. Charles Sewell, manager of the Perla plant of the Acme Brick Company allowed Resources and Development Commission personnel to take photographs of his Company's operations. Mr. Leo Frantz, Ceramic Engineer at the Perla plant, made several trips to the Company's pits with Division geologists and supplied much information on the operation of the Perla plant.

Special recognition for the development of this investigation should be given to members of the Geology Committee of the Resources and Development Commission, and to Mr. Harold Foxhall, Director of the Division of Geology. Mr. Foxhall actively supervised all phases of the work leading to this report and the preparation of the report itself.

All the members of the Division of Geology staff assisted in some way in the completion of this report and for their efforts they are warmly thanked. Mr. Hardy Winburn and Mr. Sinclair Winburn of the Winburn Laboratories put considerable time and effort into the earlier part of this investigation, offering much timely advice and furnishing all of the preliminary firing data on the samples collected by the Division of Geology.

STRATIGRAPHY

Tertiary System

The Tertiary system is represented in Arkansas by sediments of Paleocene, Eocene and possibly Pliocene age. No detailed breakdown of the Tertiary groups has yet been published that carries into Arkansas the formations as recognized in other states. However, J. A. Gardner, of the U. S. Geological Survey, in an unpublished manuscript (1944), has subdivided on the basis of faunal zonation the Midway group of the bauxite region.

Paleocene Series

MIDWAY GROUP

The outcrop of the Midway group in the area of this report occupies a strip as much as 5 miles wide extending southwest from Little Rock across Pulaski, Saline, and Hot Spring counties for a distance of 50 miles. Based on localities studied in Saline and Pulaski counties, J. A. Gardner (1944), tentatively recognized the equivalents of the two upper members of the Kincaid formation and both members of the Wills Point formation as being present on the outcrop in this area. Gardner found more points of resemblance to the Texas section than to the

Midway of Tennessee, partially because the Clayton and Porters Creek in Tennessee have been worked in less detail. Local usage, however, has favored Porters Creek and Clayton, and for that reason these terms are retained in the present report.

Porters Creek Formation

The Porters Creek formation lies conformably on the Clayton formation and is typified by gray to dark blue clays that vary from blocky to plastic in character and which contain siderite nodules and lenses. Gardner has reported (1944) that in places the lower member carries a superb micro-fauna.

Clayton Formation

The Clayton formation where present along the outcrop in this area, lies unconformably on Paleozoic rocks or locally on intrusive igneous rock (Cretaceous?) in Pulaski and Saline counties. It is characterized by Gardner (1944) as being a "succession of indurated fossiliferous sandy limestones and lime sandstones separated by loose or loosely indurated calcareous sand or, at a few localities, by clay beds" and is commonly referred to as the "Midway Lime" or the "Calcareous Midway".

Eocene Series

WILCOX GROUP

Lying over the marine beds of the Midway group in central Arkansas, locally unconformable, is the nonmarine predominantly sandy, partially lignitic, Wilcox sequence. The Wilcox is about 850 feet thick in this area and its outcrop occupies a southwest-trending band which varies in width from 6 miles in the vicinity of Little Rock to 21 miles in the section across southern Hot Spring and northern Dallas counties. The group is made up principally of fine to very fine cross-bedded sands, silty sands and clayey sands that are for the most part light colored. The lower 50 to 100 feet is characterized in most of the area by lenticular beds of carbonaceous clays and lignite, that may occupy almost the entire interval. Most sands are white to gray on fresh surfaces with weathered exposures showing the characteristic yellows, reds, browns and buffs of iron oxide. Associated with the sands are clay lentils from 6 inches to 30 feet in thickness and varying in areal extent from a few square feet to 40 acres or more. The clays are commonly light gray except when tinted by lignite particles to brown or shades of lavender. The clays are very plastic when pure but decrease in plasticity as the percentage of silt and lignitic material increases.

Concretions and lenticular beds of siderite are encountered throughout the section, most of the material at the surface being completely oxidized. In some parts of the section the sands are well enough cemented to appear as quartzitic masses.

In the bauxite region of Pulaski and Saline counties and possibly extending farther to the south, the lowest Wilcox is represented by deposits of bauxite and kaolinitic clay, the bauxite being localized primarily around two syenite stocks and a few lesser intrusives of Cretaceous age. This zone probably represents earliest Wilcox time (Bramlette, 1935, p. 6). The overlying beds are predominantly lignitic at the base through much of the area and from the plant fossils collected in several localities in the area, E. W. Berry has demonstrated that the beds are of middle Wilcox age (1916, p. 37). It seems probable that these middle Wilcox beds are correlative with the Holly Springs of Mississippi, Tennessee and Kentucky. It is also possible that the upper beds represent the lithologically very similar Grenada formation, recognized on the eastern side of the embayment.

CLAIBORNE GROUP

The Wilcox group in this area is overlain nonconformably by the sands, lignites and carbonaceous clays of the Claiborne group. Lower Claiborne formations are believed to be missing in the area due to overlap (Stephenson & Crider, 1916, p. 66) and according to Spooner (1935, p. 122) the outcropping Claiborne in Grant County is Cockfield. It is possible that a part of the sediments in this area, now considered to be Wilcox in age, may in reality prove to be Claiborne on further detailed study. This has been suggested by recent surface mapping on the Claiborne and Jackson in eastern Arkansas done by Pope Meagher*, Carter Oil Company, and L. J. Wilbert*, University of Kansas Graduate School.

Pliocene Series

The mantle of gravel covering the area of this report and the low hills in much of the rest of the Tertiary outcrop of the state has been assigned to both the Pliocene and the Pleistocene by various authors. Branner referred to them as being late Tertiary or Pleistocene in age

* Personal communication.

(1908) as did Siebenthal (1891). Bramlette (1935) states that probably in late Tertiary time several feet of gravel accumulated on a surface that now stands at an elevation of 350 to 400 feet in the area. Later erosion has largely spread the material at lower levels.

Quaternary System

Much of the Tertiary is masked along the major streams and their principal tributaries in this area by Pleistocene and Recent sands, clays, and gravels. The deposits vary in thickness from a few feet along minor tributaries to over a hundred feet in the valleys of major streams and as a whole consist of unconsolidated light-colored materials.

MINERALOGY

MINERAL COMPOSITION OF THE WILCOX CLAYS OF ARKANSAS

By VICTOR T. ALLEN

The principal mineral of the clays of the Wilcox formation examined during this investigation is kaolinite, a hydrous aluminum silicate ($H_4Al_2Si_2O_9$). Other minerals that occur in significant amounts are listed in the order of their abundance in Table 1, and include quartz, silicon dioxide (SiO_2), a clay mineral of the montmorillonite group in which ferric iron substitutes for alumina, [(Mg, Ca) O. (Al_2O_3, Fe_2O_3). 3 SiO_2.n H_2O] and muscovite, (H, K) $AlSiO_4$. A few grains of zircon (Zr SiO_4), rutile (TiO_2), tourmaline H_9Al_3 $(B_3OH)_2$ Si_4 O_{19} and apatite Ca (Cl, F)Ca_3 $(PO_4)_3$ are present in some samples.

These minerals were identified by petrographic methods employed on the powdered clay immersed in oils of a known index of refraction (Larsen and Berman, 1934) and on standard petrographic thin sections ground to .03 mm. from lumps of the crude clay. As a check on the determination of the mineral composition, sample HS No. 1, which is representative of the clays listed in Table 1, was sent to Dr. Ralph E. Grim of the Illinois State Geological Survey for X-ray and differential thermal analyses. His report follows:

> The differential thermal curve shows the characteristic reactions for kaolinite but of lower intensity than would be true if the sample were substantially pure kaolinite. The slight initial endothermic reaction suggests a small amount of montmorillonite. The exothermic reaction between about 250° and 700° is due to organic material.
>
> An X-ray diffraction pattern shows the presence of kaolinite, montmorillonite, and quartz.

The optical properties of the bulk of the clay minerals in each sample are similar to those given by Ross and Kerr (1931) for kaolinite. In thin section some areas are stained brown

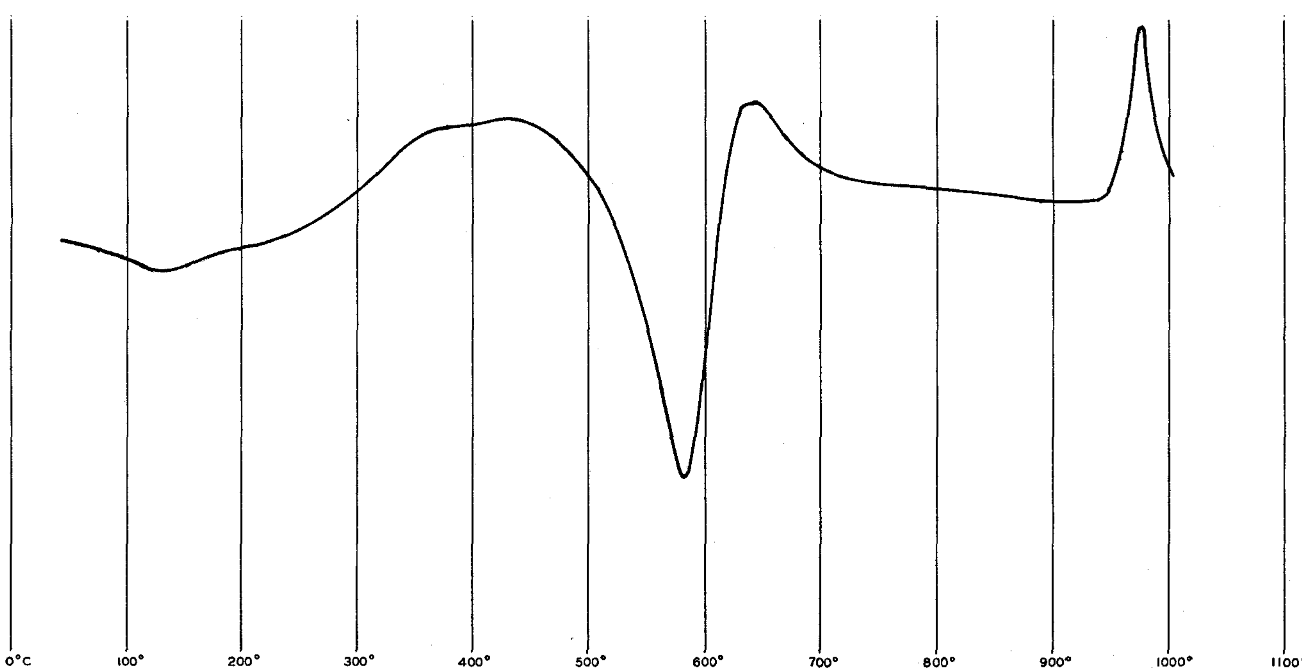


Figure 2. Differential Thermal Curve of HS-1.

or black with organic material. Locally, patches and filled cracks consist of a clay mineral with higher interference colors and indices of refraction that resemble the clay minerals of the montmorillonite group. The brown color in ordinary light and the indices of refraction suggest that ferric iron substitutes for alumina in the clay mineral (Ross and Shannon 1926; Ross and Hendricks, 1945). The ferric oxide, magnesia and possibly some of the soda and potassium listed in the chemical analyses of the samples given as Table 5, page 25 are to be assigned to this mineral. Some of the ferric oxide is present as stains. Part of the potassium occurs as shreds of muscovite .002 mm. wide and .1 mm. long. Some of TiO_2 reported in the chemical analyses occurs as tiny needles of rutile visible in thin sections (see Plate I).

Grains of quartz are present in each sample and vary from those visible with a high power objective to a maximum length of .2 mm. Many of the grains range from .01 to .1 mm. in major diameter. The amount of quartz varies in the thin sections studied from about 15 per cent to 40 per cent.

Some general relationships have been noted between the minerals present and the ceramic properties of the respective clay. Kaolinite is the essential mineral in many clays which are plastic and refractive or resistant to heat. The plasticity and burning behavior are modified by the presence of other minerals. Organic material, montmorillonite and minerals consisting of exceedingly fine-grained crystalline plates tend to increase the plasticity. Muscovite, montmorillonite and minerals containing potassium, iron and lime in large quantities lower the fusion point of the clay. The relative low content of these compounds shown in the chemical analyses are favorable features of these clays. Finally, the amount and the size of the quartz grains influence the shrinkage and the temperature at which the clay is fired.

TABLE 1

Mineral Composition of Wilcox Clays of Arkansas

Sample	D-7	G-1	HS 1	HS 6	HS 7	HS 15
Kaolinite	X	X	X	X	X	X
Quartz	X	X	X	X	X	X
Montmorillonite	X	X	X	X	X	X
Muscovite	X	X	X	X	X	X
Zircon	X	X	X	X	X	X
Rutile	X	X	X			
Tourmaline	X					X
Apatite			X	X		

ORIGIN OF THE MINERALS IN THE WILCOX CLAYS OF ARKANSAS

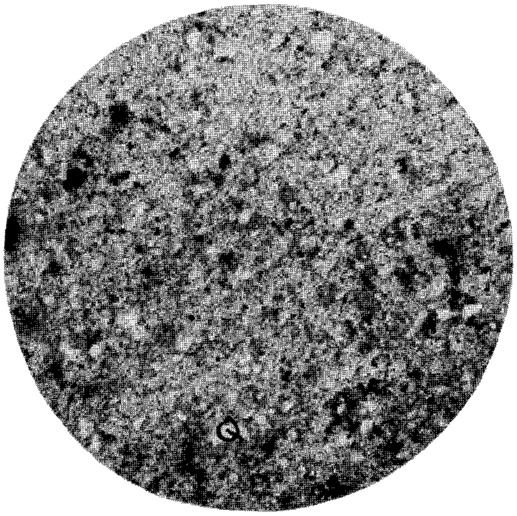
This statement of the origin of the minerals in the Wilcox clays applies to those listed in Table 1, which were examined petrographically. Kaolinite is formed by weathering of aluminous minerals such as feldspars under conditions of thorough leaching. Long continued weathering under neutral to acid conditions aided by a favorable climate and physiography permits ground waters to penetrate deeply and form deep deposits of kaolinite (Ross and Kerr, 1930). Under conditions of poor drainage and alkaline solutions montmorillonite minerals are formed from suitable source rocks. Montmorillonite minerals have been reported by Ross (1941) at Magnet Cove, Ark., as the product of alteration of volcanic ash and in the water-laid volcanic rocks of early Upper Cretaceous age in Southwestern Arkansas (Ross, Miser, Stephenson, 1928).

The clays of the Wilcox formation of Arkansas are sedimentary and consist of minerals derived from source rocks which contained kaolinite, montmorillonite, muscovite, quartz and other minerals. These were eroded, mixed during transportation and deposited in the Eocene sea in the area where they now occur. Clays that have a similar origin and geologic history have been described at other localities (Allen, 1946).

PLATE I

1. Photomicrograph of Wilcox clay (D.7) showing kaolinite (gray), quartz (white, Q) and organic matter (black).
2. Photomicrograph of Wilcox clay (G.1) showing kaolinite (gray, K), quartz (white, Q), montmorillonite (M), shred of muscovite (MU) and organic matter (black).
3. Photomicrograph of Wilcox clay (HS1) showing area of kaolinite and montmorillonite (KM) cut by montmorillonite (M), also kaolinite (K), quartz (white, Q), and organic matter (black).
4. Photomicrograph of Wilcox clay (HS6) showing area of montmorillonite (M) surrounded by clay mainly kaolinite, with a little muscovite, quartz and organic matter.
5. Photomicrograph of Wilcox clay (HS7) showing quartz (white, Q), kaolinite (K), and dark spots of organic matter.
6. Photomicrograph of Wilcox clay (HS15) showing area of montmorillonite (M), quartz (white, Q), kaolinite (gray, K) and dark spots of organic matter (black).

All Photomicrographs are the same scale.



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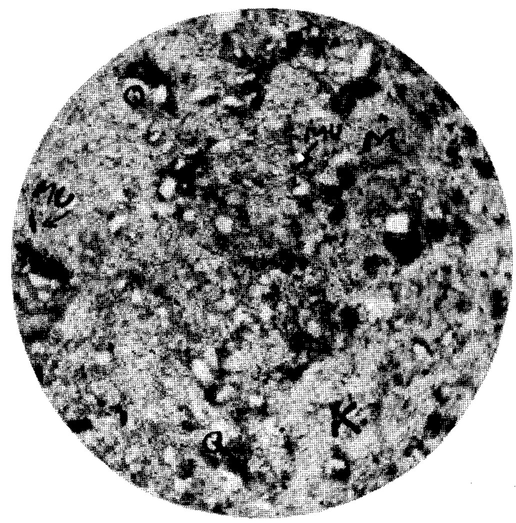

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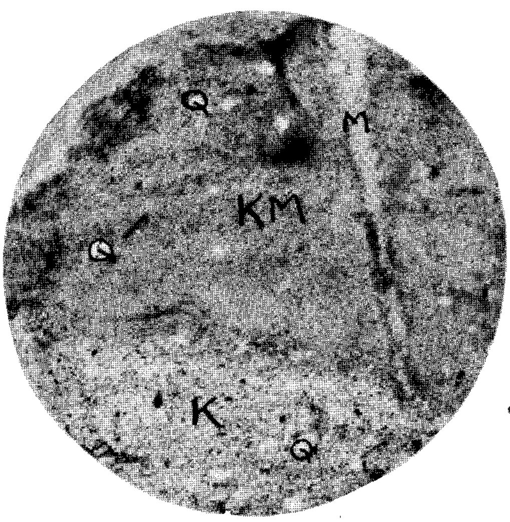

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3

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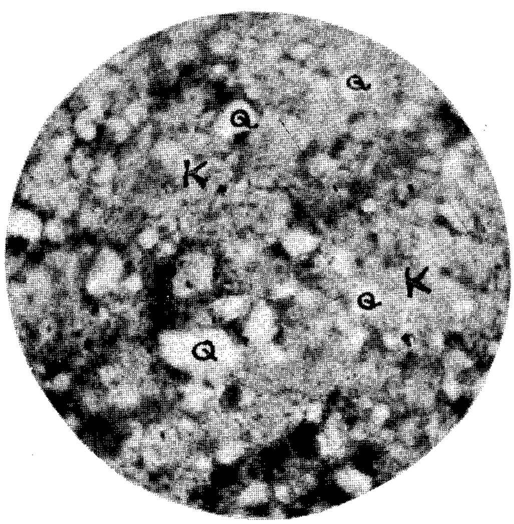

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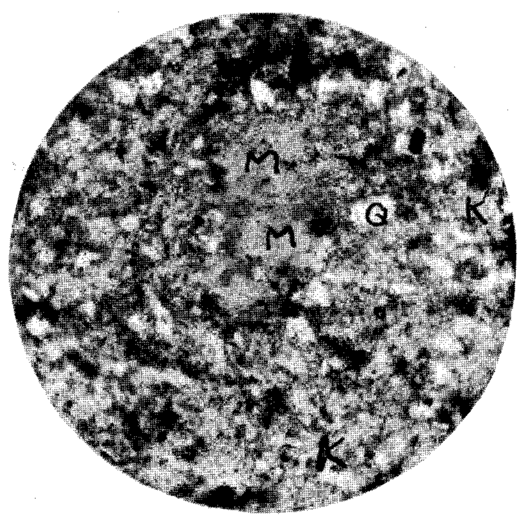

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CHAPTER II—CERAMICS

GENERAL CLASSIFICATION AND DESCRIPTION OF CLAYS

General

Despite the fact that clay is the commonest and the most abundant of our mineral resources the descriptive terminology is greatly confused by the geologist and ceramist as well as the layman. This is in part due to the almost infinite variety of clays, and in part to the fact that the classifications, definitions and descriptions are based on varying points of view. A brief classification proposed by Whitlach (1940, pp. 9-10) is a good illustration of the geologists point of view. A slightly modified version of Whitlach's classification follows:

Classification of Clays, Based on Geologic Origin

A. Residual clays
  Surface residuals formed by weathering of bedrock.
    Primary kaolins from granite, pegmatite, etc.
    Ferruginous clays from limestones, shales, loess, or other bedrock strata; common types of surface clays.
  Subsurface residuals, formed by ascending or descending waters of supposed meteoritic origin.
    Kaolin and bauxitic clays.
    Clays associated with iron-ore deposits.
  Subsurface residuals, formed by ascending water of possible igneous origin.

B. Sedimentary (transported) clays.
  By waters into lakes, swamps, or shallow seas.
    Shales.
    Underclay of fire-clay type.
    Ball clays, plastic fire clay, siliceous fire clay (wad, sagger and bond clay). Illustrated by the clays of the Wilcox group.
    Kaolin.
    Bentonite (transported in part by wind).
    Alluvial clay.
    Colluvial clay. Deposits formed by wash from any other type of deposit.
  By wind.
    Loess (transported in part by water).
    Bentonite (transported in part by water).
  By ice.
    Glacial clay.

It will be noted that Whitlach was forced to use the terms "fire clay" and "ball, wad and sagger clays" that are derived from the utilization of the clays rather than from geologic origins.

Definitions

In this connection it would be well to define a few of the terms used in this report to describe the clays of the Wilcox group in Arkansas. The following definitions were proposed by the Committee of Geological Surveys of the American Ceramic Society (Ries, and others, 1939, pp. 213-214).

Clay: A naturally occurring earthy aggregate in which hydrous silicates of alumina usually predominate. It is usually plastic when sufficiently pulverized and wetted, rigid when dry, and becomes steel-hard when fired at a sufficiently high temperature.

Ball clay: A very plastic fine-grained refractory clay firing usually to a white or ivory color but sometimes to light buff. It commonly fires to a low-absorbent body between cones 5 and 10, but as high as cone 15 in some cases. It remains light in color and does not over-fire at whiteware temperatures. Its function is chiefly that of a bonding or suspending agent.

Bond clay: A clay of high plasticity and high dry strength which may or may not be refractory and is used to bond non-plastic materials such as foundry sand.

Fire clay: A clay of either sedimentary or residual character which has a P.C.E. of not less than cone 19. It may vary in its plasticity or other physical properties and while it often fires to a buff color, it does not necessarily do so.

Filler clay: Any clay used in a crushed or ground state for purposes other than the production of ceramic materials or products, and generally behaving as an inert ingredient.

Sagger clay: A fire clay or ball clay suitable for sagger manufacture and of suitable bonding quality. It may resemble a bond clay in plasticity, but it contains more impurities and may be more siliceous.

Wad clay: A clay of high plastic tensile strength and plasticity which can be used to make a joint between saggers and other refractory material.

Relationship Between Mineral Composition and Physical Properties

A classification or description of clays based on the kind, proportion and particle size of minerals present would be the most accurate that could be devised, but the most difficult to achieve. The relationship between the mineral composition and the physical properties of clays is summarized in the abstract of an article by Grim (1939). To quote from the abstract (p. 141):

> The clay minerals occur in flake-shaped particles, possess base-exchange capacity, and exist in or are reducible to extremely small grain sizes on working with water. Different clay minerals possess these properties in varying degrees.
>
> The clay mineral component is the chief factor determining the properties of a clay. In general, plasticity and bond strength caused by the clay mineral decrease in the following order: montmorillonite, illite, and kaolinite. In many clays, the plasticity and bond strength mainly result from the presence of montmorillonite minerals or some members of the illite group, although these constituents may compose only minor amounts of the clay. . . . The green properties of clays are also related to the character of the exchangeable bases carried by the clay minerals. . . . The properties of clays are related further to the effective size-grade distribution developed in use which frequently differs from the size-grade obtained by mechanical analysis.

The most important clay minerals are kaolinite, montmorillonite, and the illite group. By far the most important non-clay mineral, quantitatively, is quartz and the one second in importance is calcite. In some instances the iron oxide, which may be present in a variety of minerals other than hematite, determines the final usefulness of a clay, although present in comparatively small amounts. A number of other minerals are commonly present in clay, but their total effect is small.

Pure kaolinite contains no iron oxide and fires to a white color. Its plasticity and bond strength are low, and shrinkage on drying and firing comparatively low, although the amount of shrinkage varies with the particle size, as also does the plasticity. Kaolinitic clays, such as ball clays, tend to have a fairly high drying shrinkage and a long firing range. Kaolinite is also exceedingly refractory and open burning at high temperatures.

The illite clay minerals contain iron, potassium and magnesium as integral constituents of the crystal lattice. The iron oxidizes to hematite and other compounds on firing, resulting in a red, brown or gray color. All three elements act as fluxes and reduce the fusion point and ultimate firing temperature of the clay, resulting in low temperature for firing and vitrification. In many instances the drying shrinkage of illite shales is relatively low, possibly due to the fact that the shales do not break down to their ultimate particle size, but throughout their working remain in fairly large aggregates. The firing shrinkage of illites is high in comparison to kaolinitic clays, and the firing range is much shorter. Illite clays also tend to bloat at vitrification.

Owing to the high base exchange capacity of montmorillonite, sodium, potassium, magnesium, iron, and calcium ions are likely to be present, increasing the fusibility and firing shrinkage. It is almost impossible to produce a brick or other form from a high montmorillonite clay because of the high drying and firing shrinkages. In some types of illite similar results are produced. A very small proportion of montmorillonite or similar illites in a kaolinitic clay will have rather extreme effects on the physical properties, resulting in high plasticity and bond strength, and relatively low porosity when fired to moderate temperatures. The refractoriness of the clay is also reduced.

Due to the decided differences in the physical properties of these clay minerals it readily can be seen that varying proportions can produce an enormous variety in the ceramic characteristics. Differing particle size in the worked clay introduces still another variable in plasticity, bonding quality, shrinkages and firing range.

Very few clays are free from some proportion of quartz, ranging from sand size to particles as small as the largest size in the clay fraction. Quartz, however finely divided it may be, is almost completely non-plastic, and although much more refractory than montmorillonite or illite, not nearly so refractory as kaolinite. Furthermore, combinations of pure quartz and pure kaolinite are less refractory than either alone. The quartz present in the relatively high grade clays such as ball clays and plastic fire clays is nearly identical to the finely pulverized silica sold as potters' flint, and the additions of potters' flint to a ceramic body produce results similar to the natural mixtures of clay and finely divided quartz. The clay is "opened up" by the quartz, that is, the clay particles are separated. In drying this produces less shrinkage and less tendency toward warping because the water can more easily migrate to the outside of the shape in the drying process. In firing similar results are produced. The general effect is to raise the level of firing temperatures and in many cases the firing range. If the silica or quartz is present in relatively large amounts the quartz inversions accompanied by expansion may result in expansion of the whole, and some cases cause disruption. Highly siliceous clays tend to remain porous with little change in absorptions to relatively high temperatures. But as vitrification is approached porosity decreases rapidly. In other words, the vitrification range is actually short. The pyrometric cone equivalent of siliceous clays is usually lower than less siliceous, but basically similar kaolinitic clays.

Clays of the Wilcox Group

The clays of the Wilcox group can be considered as mixtures chiefly composed of kaolinite and quartz, with varying but relatively small amounts of montmorillonite (and perhaps illite). Rutile and some form of iron oxide, probably limonite, produce minor effects in the fired clays. The kaolinite tends to produce white color, high fusion temperatures, and moderate drying and firing shrinkage. Those high in kaolinite are the white-firing ball clays. Those containing a larger proportion of montmorillonite have their plasticity, bonding qualities, and shrinkages increased. Firing range and the level of firing temperatures, on the other hand, are reduced by the greater amount of montmorillonite. Due to the fact that the montmorillonite contains ferric iron as a substitute for the alumina in the molecule the fired color is darkened in proportion to the amount of montmorillonite present. Illite would produce the same effect. Those containing moderate amounts of montmorillonite are the plastic fire clays or sagger clay. As the montmorillonite is further increased in proportion to the kaolinite the color becomes darker, the drying and firing shrinkages high, and the firing range low and quite short. The wad clay and low grade plastic fire clays belong in this group. If the montmorillonite dominates the physical properties of the clay we find clays firing to salmon, and brownish colors, and having excessive shrinkages, accompanied by warping and cracking, low firing temperatures, short firing range and low fusion temperatures.

If the clay is largely a mixture of kaolinite and quartz the white color is retained, but shrinkages are decreased, and higher temperatures are required for producing low porosity as the quartz content increases in proportion to the kaolinite. The siliceous clays are also less refractory, but the difference is not marked.

A siliceous clay containing a relatively large amount of montmorillonite may prove useful for lower grade products because the quartz tends to offset the excessive shrinkage and high plasticity of that clay mineral, but the changes are analagous to those in which the dominant constituents are kaolinite and montmorillonite. That is, as the montmorillonite increases the plasticity and drying and firing shrinkage, and colors due to iron compounds are deepened. As an example, a highly siliceous clay containing a fairly large proportion of montmorillonite may be quite plastic, but tend to be sticky. Drying shrinkages will be moderate. Porosity will be reduced to a commercial minimum only at a fairly high temperature, but the firing range will be short, with a possibility of over-firing or bloating as the clay approaches vitrification.

Calcite is a very minor constituent of the Wilcox clays on which chemical analyses are available, and there is no evidence in the ceramic analyses to indicate an appreciable amount of calcite, or calcium carbonate, in any of the samples tested. Calcium carbonate, or other calcium carbonate compounds, produces very decided effects in clays containing more than one or two per cent. It shortens the firing range and the vitrification range. If present in fairly large amounts the clay will remain porous throughout most of its firing history. A few degrees above the point where normal shrinkage and reduction of porosity begins the clay will start to fuse. Small amounts of calcite, if present in the finely divided form, may prove beneficial in neutralizing the color due to iron oxide. Calcite particles in sizes larger than 30-mesh are likely to cause lime spots or even complete disruption of the material due to slaking of the quick lime formed in firing.

LABORATORY TESTING PROCEDURE

General

The testing of clays to determine their ceramic usefulness largely consists of following as closely as possible the methods used in manufacturing ceramic articles, accompanied by observations, weighing, and measuring in order to obtain qualitative and quantitative data that can be used to evaluate the clays and to compare them to other clays similarly tested.

The test methods used in this investigation follow rather closely the recommendations of the Committee on Standards of the American Ceramic Society (Watts and others, 1928) and the standard testing procedures of the American Society for Testing Materials for testing brick (A.S.T.M. designation: C 67-44) and those for testing refractories (A.S.T.M. designations: C 20-46 and C 24-46). As can be inferred from the A.S.T.M. designations, the methods are designed for testing clays for use in structural products and refractories, but are nearly as useful in determining the suitability of a clay for use in other types of product. Owing to the small size of the samples available some modifications in methods were necessary.

The raw clay samples were crushed with a mortar and pestle to pass a 20-mesh screen. The portion reserved for the tests was weighed out and twenty-five per cent distilled water mixed with the clay, and allowed to stand over night in a closed container. The next day the clay-water mixture was thoroughly wedged in order to obtain uniform wetting. If preliminary working indicated insufficient water, more was added, and if the clay was too wet it was allowed to dry for a short time. The proper consistency of the clay was judged to be near the lower limit of the plastic range, or just short of the point where deformation of the clay mass produced surface cracks. This produces a working consistency close to that used for stiff mud extrusion, but somewhat more yielding.

The plastic clay was shaped by hand into small bricks in two sizes. The smaller size were approximately three-fourths inch square by three inches in length. The larger size were one inch square by seven inches in length. Marks for determining linear shrinkage were placed on the bricks with a tram. After forming the plastic bricks were weighed in air, and a portion were weighed submerged in kerosene in order to determine plastic volume.

After drying at room temperature the bricks were placed in an electrically heated drier thermostatically controlled within the temperature range of 210° and 230° F. The dried bricks were weighed and measured and volumes determined on a portion by the displacement of kerosene.

The test bricks were fired in a Globar type electric kiln having approximately one cubic foot capacity. The rate of heating was relatively slow. Total firing time varied from 18 hours to 30 hours. When maximum heat had been attained the bricks were held at this temperature for approximately an hour in order to equalize the temperature within the kiln. Temperatures were indicated and recorded by a thermocouple and recording pyrometer. The end-point was determined by means of pyrometric cones placed with the bricks. Oxidizing conditions were maintained in the kiln at all times.

After firing the bricks were again weighed and measured, and then submerged in water at room temperature for twenty-four hours, after which they were wiped free of surface water and weighed. Following this the bricks were submerged in boiling water for three hours and after cooling allowed to soak for another twenty-four hours. We find this procedure produces a degree of absorption equivalent to five hours submersion in boiling water. The bricks are again wiped free of surface water and weighed both in air and in water for the purpose of determining absorption, porosity and fired volume.

The test bricks were fired to five different temperature levels ranging from cone 05 to cone 13. The procedure outlined above was followed after each firing.

Plastic, Dry and Original Properties

Original color.—The color of the dry clay before grinding was noted. Owing to extreme differences in personal judgment of color the color record is of minor significance.

Plasticity.—The plasticity of the clay was determined by personal judgment in handling the clay during the process of preparation and molding. The terms very plastic, plastic, fairly plastic, lean (or slightly plastic) as used in this report are relative only.

Workability.—The workability of the clay was judged by the ease or difficulty experienced in hand molding the bricks. Unless the clay was especially smooth, crumbly, or sticky this property was merely recorded as "satisfactory."

Drying behavior.—If warping, cracking, scumming or cupping were noted the fact was recorded, otherwise drying behavior was recorded as "satisfactory" or "O.K."

Water of plasticity.—The water of plasticity is the percentage of tempering water used to bring the clay to the best working consistency. Owing to the fact that the best working consistency rests with the personal judgment of the operator the water of plasticity is not an absolute value. We find in our laboratory, however, that the amount of tempering water used in any one clay seldom varies over two per cent even when results of previous tests are not consulted. We believe that the water of plasticity in a continuous series of tests such as this is comparable, and reproducible within moderate limits.

The water of plasticity is calculated from the formula:

$$\frac{\text{Plastic weight} - \text{Dry weight}}{\text{Dry weight}} \times 100 = \text{Per cent water of plasticity}$$

Shrinkage water.—Shrinkage water is defined as that portion of the water of plasticity which is driven off up to the point where shrinkage ceases. The balance is "pore water". These properties are important in that they are related to the drying behavior of the clay, and are helpful in determining problems that will be encountered in commercial utilization.

Pore water.—This property is discussed under shrinkage water, and is determined by subtracting the percentage shrinkage water from the percentage water of plasticity.

Volume shrinkage on drying.—The shrinkage of a clay from the plastic to the dry state is of considerable importance. Clays having excessive shrinkage cause serious difficulties in some applications, especially in structural clay products where freedom from warping and close size tolerance are desirable. The formula used for calculation is:

$$\frac{\text{Plastic volume} - \text{Dry volume}}{\text{Dry volume}} \times 100 = \text{Per cent volume shrinkage on drying}$$

Measured linear shrinkage.—Linear shrinkage as indicated by the decrease in distance between measured marks on the face of the brick is calculated from the formula:

$$\frac{\text{Plastic length} - \text{Dry length}}{\text{Dry length}} \times 100 = \text{Per cent measured linear shrinkage}$$

Calculated linear shrinkage.—The calculated linear shrinkage is derived from the volume shrinkage in the formula:

$$100\left[\sqrt[3]{1 + \frac{\text{per cent volume shrinkage}}{100}} - 1\right] = \text{Per cent calculated linear shrinkage}$$

If the shrinkage of the brick were uniform in all directions the calculated linear shrinkage would be exactly equal to the measured linear shrinkage. Actually this is very seldom the case both because the linear measurements are more subject to error than the volume determinations, and because shrinkage is more likely to be greater in the small dimensions than in the large. As a result the calculated linear shrinkage is often greater than the measured shrinkage.

Fired Properties

Fired color.—One of the most important characteristics of a clay is its fired color. Color alone determines many of the uses of a clay.

Firing behavior.—Such features as warping, cracking, cupping, scumming, and bloating are recorded under the firing behavior of the clay being tested. A considerable amount of caution must be exercised in making judgments from hand-molded small bricks, especially in regard to warping which may be caused by strains set up in molding or drying that do not affect the brick until after it is fired.

Volume shrinkage.—The fired volume of a brick is determined by first weighing it in air and then weighing it submerged in water. Allowance must be made for differences in the specific gravity of the water due to temperature variations. An accurate knowledge of the shrinkage of a clay, both in drying and in firing, is important from the standpoint of maintaining size tolerances in many commercial products. Excessive shrinkage is likely to be accompanied by warping and cracking, whereas little or no shrinkage indicates underfiring. The volume shrinkage is calculated from the formula:

$$\frac{\text{Dry volume} - \text{Fired volume}}{\text{Dry volume}} \times 100 = \text{Per cent volume shrinkage}$$

It will be noted that both drying and firing shrinkages are based on the deviation from the dry dimensions. This is standard procedure because the dry dimensions are most likely to be reproducible, but the practice is at times inconvenient where total shrinkage from the plastic dimensions is needed, such as in the manufacture of brick.

Linear shrinkage (measured).—Linear shrinkage is calculated from the formula:

$$\frac{\text{Dry length} - \text{Fired length}}{\text{Dry length}} \times 100 = \text{Per cent linear shrinkage}$$

The linear shrinkage of course serves the same purpose as the volume shrinkage.

Linear shrinkage (calculated).—The volume shrinkage on firing is converted to calculated linear shrinkage with the formula used to convert volume shrinkage on drying to linear drying shrinkage. The differences between measured and calculated linear shrinkages are likely to be the same as those that occur on drying. That is, the shrinkage in the small dimensions is often greater than that in the larger dimension. In addition, cupped or concave sides may appear on the fired brick and increase the difference between calculated and measured linear shrinkages.

Absorptions.—The methods of determining absorptions has been previously described. Both the absorption obtained by submersion for twenty-four hours in cold water, and the absorption caused by submersion in boiling water for three hours are calculated from the formula:

$$\frac{\text{Weight of saturated brick—Dry weight}}{\text{Dry weight}} \times 100 = \text{Per cent absorption}$$

We consider the absorptions the most important index of the progress of the firing toward the maturity of the clay. As the absorptions approach zero higher temperatures are usually not required, and in most cases will cause bloating, deformation or other symptoms of overfiring. Many commercial specifications are based on the percentage absorption of the fired clay, and these absorptions are quite important in determining the resistance of structural wares to extreme weathering and to moisture penetration.

Saturation Coefficient.—The saturation coefficient is the ratio of the absorption by 24-hour submersion in cold water to the absorption after a 5-hour submersion in boiling water. A.S.T.M. Standard designation C 62-49 (1949, p. 567) states that the saturation coefficient "is defined generally as the ratio of easily filled to total fillable pore space. The theory of the saturation coefficient is that if only part of the total pore space is occupied by water there is room for expansion on freezing into the remaining pore space without disruption of the material. The data indicate that if the easily filled pore space, that is the maximum water that might be absorbed . . . does not exceed 80 per cent of the total pore space, the remaining space will relieve pressure due to expansion on freezing".

McMahon and Amberg (1947) conducted extensive tests to determine the correlation of saturation coefficient and absorption with freezing and thawing tests, supplemented by several years' exposure to the weather at Alfred, New York. They concluded that the ability of a brick to withstand years of freezing and thawing can be predicted with a fair degree of probability from absorptions and saturation coefficients, but that the strength of the fired clay and the method of manufacture should be taken into consideration. In our laboratory we have found that kaolinitic plastic fire clays tend to have saturation coefficients that are high in comparison to the absorptions determined by boiling water. This difficulty can be overcome by burning the brick to temperatures sufficiently high to produce brick with low absorption and high strength.

Apparent porosity.—The apparent porosity is determined by converting the weight of water absorbed by the brick to volume. By this means the approximate volume to pore space to the total volume of the brick can be determined. The formula used is:

$$\frac{\text{Saturated weight—Fired weight}}{\text{Fired volume}} \times 100 = \text{Per cent apparent porosity}$$

Apparent specific gravity.—As determined, this property approximates the true specific gravity in that the amount of open pore space, as indicated by the water absorbed on boiling, is subtracted from the volume. The volume occupied by sealed pores would have to be known to obtain the true specific gravity. The apparent specific gravity is obtained with the formula:

$$\frac{\text{Weight fired}}{\text{Volume fired—(Saturated weight—Fired weight)}} = \text{Apparent specific gravity}$$

Bulk specific gravity.—The bulk specific gravity is the density of the fired clay in grams per cubic centimeter. The bulk specific gravity is less than the apparent specific gravity, but as the clay approaches vitrification the two values become numerically closer. The bulk specific gravity is of importance to the manufacturer of structural clay products and of refractories in that it determines the tonnage of material he will have to handle and burn in order to obtain a product of given dimensions.

Hardness.—A steel file was used as a standard for determining the relative hardness of the fired test bricks. The hardness is reported as softer than steel, steel hard, and harder than steel. If the fired clay is at least steel hard it can be considered well matured in the firing process.

Best firing range.—The firing range of each clay is estimated from a study of the fired properties such as shrinkage, absorption, saturation coefficient and hardness. The estimate given in this report is intended to fit the requirements for face brick of a high grade. The range will naturally deviate from this estimate for other types of product. It is useful in that it gives a rough approximation of the temperatures required, and especially in that the length of the firing range, regardless of the level, is of major importance. Clays having firing ranges shorter than the easily controlled limits of temperature in commercial kilns are ordinarily not usable.

Pyrometric cone equivalent.—The P.C.E. or pyrometric cone equivalent of a clay is determined by comparing its softening or deformation point with that of standard pyrometric cones. These are small tetrahedrons composed of ceramic materials consisting largely of clay and silica in the higher temperature range. The standard cones partially fuse, causing them to deform with the tip of the cone bending toward the base. The clay cones to be tested are mounted on a small disk-shaped plaque made of refractory materials. The clay cones are the same size and shape as the standard cones, and are mounted alternately with them. The tests conducted for this report were made in a gas-fired furnace designed for this specific purpose by the American Refractories Institute, and were in accordance with A.S.T.M. Standard designation C 24-46.

Most of the clays included in this report are sufficiently refractory to be classed as fire clays. The minimum pyrometric cone equivalent for the various classes of fire clay refractories has been fixed at various points within the past several years. The latest A.S.T.M. classification is given below.

TABLE 2

Standard Classification of Fireclay Refractories

A.S.T.M. designation C 27-41 (1949 edition)

Class of fire clay	Pyrometric cone equivalent (minimum)
Super duty fireclay brick	cone 33
High heat duty fireclay brick	cone 31-32
Intermediate duty fireclay brick	cone 29
Low duty fireclay brick	cone 19

CERAMIC PROPERTIES

The properties determined by the ceramic tests, their general significance, together with methods and equipment used are described in the section on laboratory procedure. For convenience of comparisons all ceramic data on the 23 samples tested are included in Table 4. The main body of this report will be found, however, under the separate discussions of each clay sample, where the tabulated data are repeated and briefly evaluated. Specific suggestions for possible utilization of the clays, as indicated by the data, are also included in this section.

It will be noted that all numerical ceramic data are reported two places to the right of the decimal, but the reader should be cautioned that in most cases only the first two digits of the number, regardless of the decimal point, should be considered accurate.

Throughout the discussion and tabulation of ceramic properties repeated reference has been made to pyrometric cones, but temperatures are seldom mentioned in the conventional Fahrenheit or Centigrade scales. The practice of referring to firing temperatures of ceramic materials in terms of pyrometric cones has a sound basis. Pyrometric cones measure temperature plus time, or heat work. For example, the temperature required to bring down cone 4 may vary from 2075° to 2200° F., depending on the rate of heating. For convenience of reference the softening, or end point, of Standard pyrometric cones at prescribed temperatures and rates of heating are given in Table 3.

TABLE 3

Temperatures of Fusion (End Points) of Standard Pyrometric Cones When Fired Rapidly and Slowly.

(Fairchild and Peters, 1926, p. 738)

Cone number	When fired slowly (20° C. per hour) Degrees C.	Degrees F.	When fired rapidly (150° C. per hour) Degrees C.	Degrees F.
07	975	1787	990	1814
06	1005	1841	1015	1859
05	1030	1886	1040	1904
04	1050	1922	1060	1940
03	1080	1976	1115	2039
02	1095	2003	1125	2057
01	1110	2030	1145	2093
1	1125	2057	1160	2120
2	1135	2075	1165	2129
3	1145	2093	1170	2138
4	1165	2129	1190	2174
5	1180	2156	1205	2201
6	1190	2174	1230	2246
7	1210	2210	1250	2282
8	1225	2237	1260	2300
9	1250	2282	1285	2345
10	1260	2300	1305	2381
11	1285	2345	1325	2417
12	1310	2390	1335	2435
13	1350	2462	1350	2462
14	1390	2534	1400	2552
15	1410	2570	1435	2615
16	1450	2642	1465	2669
17	1465	2669	1475	2687
18	1485	2705	1490	2714
19	1515	2759	1520	2768
20	1520	2768	1530	2786
			180° C. per hour	
23			1580	2876
26			1595	2903
27			1605	2921
28			1615	2939
29			1640	2984
30			1650	3002
31			1680	3056
32			1700	3092
33			1745	3173
34			1760	3200

Whitlach, in his "Clays of West Tennessee" (1940, pp. 348-355) reports a large number of ceramic analyses of Wilcox clays. A comparison of these analyses with those given for the clays of the Wilcox group in this report shows that the range in properties is the same. For any one Arkansas clay here reported a clay analysis similar in most respects can be found among the Tennessee clays. This fact is cited not so much in proof of the well-known similarity of the Wilcox clays in Tennessee and Arkansas, but in confirmation of the validity of the data recorded in Table 4.

DISCUSSION OF THE RESULTS OF CERAMIC TESTS

Although the number of clays tested for this report are relatively few it can be assumed that the sampling was random and fairly representative of the clays of the Wilcox group as they occur in Arkansas.

The most outstanding general characteristic revealed by the ceramic tests reported here is variety. In refractoriness the clays vary from the high heat duty class to those that have a P.C.E. below the minimum requirement for low heat duty clays. Perhaps the greatest uniformity is in fired colors that for the majority of the clays range from nearly white to buff. The few exceptions fire to light reds or brown. Colors of the unfired clay, however, range from dark grayish brown to nearly white. In general the clays are plastic, but a few of the more siliceous ones are rather lean. Drying shrinkages are high on the more plastic clays, and relatively low on the less plastic, siliceous clays. In most cases the firing range is quite long, but a few have a short firing range. Commercial firing temperatures required to produce a matured product range from below average to above average, but in general the firing characteristics do not limit the clays in their commercial usefulness with the exception of fired colors, and the pyrometric cone equivalent of the fire clays.

Despite the great variation in ceramic characteristics there is an overall relationship, even between such extremes as sample No. HS-1 (or HS-6) and sample No. D-3. In the Dallas county samples we can see the gradation from low grade to high grade clays. Clay No. D-3 at the extreme low has a dark fired color, very short firing range, and high firing shrinkage. Samples Nos. D-5 and D-2 occupy intermediate and gradational positions. Clay No. D-1 is definitely a high grade clay.

The explanation of relationship of ceramic properties that vary within rather wide limits probably lies in the proportions of three or four major ingredients. The basic characteristic of the clays from the Wilcox group is the presence of the clay mineral kaolinite. The primary modification of the kaolinite characteristics can be attributed to varying proportions of finely divided quartz. But so long as these two ingredients make up most of the clay we do not find low grade clays, but rather clays that vary slightly in fusibility and fired colors, and that have decreased plasticity and shrinkages as the quartz fraction increases in proportion to the kaolinite. A third major ingredient is either the clay mineral illite or montmorillonite. In most ball clays, and those related to ball clays, illite is the clay mineral found to be present in addition to kaolinite. Illite and montmorillonite contains iron in the molecule, and also such fluxes as potassium and magnesium. As the proportion of illite increases the fired color becomes darker, the firing range shorter, the firing shrinkages higher, and the fusibility increases. A fourth ingredient, iron oxide, usually present in minor amounts, affects the fired color, and, to a slight degree, the fusibility of the clay. The writer believes that all the variations found in the clays included in this report can be explained on the basis of variations in the proportions of the ingredients mentioned above.

One characteristic of the clays that has not been mentioned in the report of tests on individual clays is the presence of vanadium efflorescence on the fired bricks. This efflorescence first appears as a bright greenish-yellow discoloration that eventually turns green. This efflorescence was noted on several of the lighter firing clays. In commercial products made from these clays the green efflorescence appears on a few bricks that are exposed to repeated wetting and drying. The slight green color does not affect the soundness of brick or other products made from the clay, but it is in some cases objectionable on aesthetic grounds. The efflorescence does not appear on hard-fired bricks.

UTILIZATION OF CLAYS

In comparison to such giants as the steel industry the manufacture of clay products does not rank high in dollars value, but the articles produced are basic necessities, not only to our daily living, but to our major industries.

Fortunately clay is extremely abundant, and the common, red-firing varieties are available in almost every community. The white to buff-firing and the refractory clays, however, are much less abundant. Requirements in respect to quality of finished product tend to be increasingly stringent, thus placing a greater demand on the relatively restricted reserves of high grade clays. Reports such as this are helpful in making an inventory of our national clay resources.

TABLE 4.—Data on Ceramic Tests of Clays from the Wilcox Group

Plastic and Dry Properties

Sample number	County	Location	Color of unfired bricks	Plasticity	Workability	Drying behavior	Water of plasticity, per cent	Shrinkage water, per cent	Pore water, per cent	Volume shrinkage, per cent	Linear shrinkage (measured), per cent	Linear shrinkage (calculated), per cent
D-1	Dallas	NE, 19-7S-16W	LG	P	G	O.K.	25.46	14.67	10.79	28.49	7.69	8.72
D-2	Dallas	NE, 4-8S-15W	LG	P	G	O.K.	31.04	20.66	10.38	39.88	10.50	11.84
D-3	Dallas	SE, 3-8S-15W	DG	P	G	O.K.	35.41	21.16	14.25	38.42	9.55	11.54
D-4	Dallas	NW, 6-7S-15W	G	P	G	O.K.	27.28	16.04	11.24	30.75	7.12	9.35
D-5	Dallas	C, 31-8S-15W	YG	P	G	O.K.	33.65	19.89	13.76	36.49	9.81	10.91
D-6	Dallas	C, 15-8S-17W	DG	P	G	O.K.	27.74	15.76	11.98	30.39	8.78	9.25
D-7	Dallas	SW, 25-8S-17W	Tan	P	G	O.K.	26.04	11.85	14.19	20.56	6.63	6.43
G-1	Grant	NW, 31-6S-14W	BlG	P	GS	SW	27.19	16.35	10.84	31.20	8.53	9.48
G-2	Grant	SE, 25-6S-15W	Br	P	G	O.K.	27.59	9.00	18.59	14.64	5.03	4.67
G-3	Grant	S of C, 31-6S-14W	BlG	P	G	O.K.	26.40	14.23	12.17	27.20	7.86	8.36
G-4	Grant	C of W, 24-6S-15W	Tan	P	GS	SW	28.73	16.40	12.33	30.91	7.20	9.36
G-5	Grant	SE, 25-6S-15W	RBr	P	G	SW&C	46.30	25.28	21.02	39.66	10.24	11.79
HS-1	Hot Springs	N of C, 25-4S-17W	Br	P	GSm	O.K.	32.39	14.72	17.67	24.32	4.33	7.52
HS-3	Hot Springs	SW, 2-5S-17W	LG	P	GSm	O.K.	27.61	10.60	17.01	18.46	3.55	5.82
HS-5	Hot Springs	NE, 5-6S-17W	G	P	GS	SW	25.56	15.14	10.42	29.23	7.69	8.92
HS-6	Hot Springs	C of N, 25-4S-17W	LG	P	G	O.K.	24.41	8.79	15.62	16.03	4.48	5.07
HS-7	Hot Springs	N of C, 7-5S-16W	G	P	G	SW	26.59	13.75	12.84	25.56	5.66	7.89
HS-8	Hot Springs	SE, 8-6S-16W	G&Y	P	G	O.K.	26.24	10.77	15.47	19.47	6.06	6.12
HS-15	Hot Springs	NE, 35-6S-18W	BlG	P	GS	O.K.	22.85	12.10	10.75	23.50	6.06	7.28
M-1	Miller	W½, 3-15S-28W	LG	FP	FG	O.K.	22.94	10.20	12.74	19.11	5.94	6.00
O-1	Ouachita	SE¼, 7-12S-18W	GB	P	G	SW	35.78	23.88	11.90	43.95	10.42	12.92
O-2	Ouachita	Center, 15-12S-19W	LG	P	G	SW	19.79	5.95	13.84	10.97	3.84	3.54
P-1	Pulaski	SW, 5-1S-12W	G	P	G	SW	29.59	12.94	16.65	22.55	5.48	7.02

Symbols used: (G) gray; (Y) yellow; (Bl) blue; (Br) brown; (R) red; (L) light; (D) dark; (P) plastic. Under "workability" (G) good; (GS) fairly good, but sticky; (GSm) good and smooth. Under "drying behavior" (O.K.) indicates satisfactory; (SW) slight warping; (C) some cracking.

TABLE 4.—Data on Ceramic Tests of Clays from the Wilcox Group (Continued)

Fired Properties

Sample number	Fired to cone	Fired color*	Volume shrinkage, per cent	Total volume shrinkage, per cent	Linear shrinkage (measured), per cent	Linear shrinkage (calculated), per cent	Total linear shrinkage, per cent	Absorption, cold water, per cent	Absorption, boiling water, per cent	Saturation coefficient	Apparent porosity, per cent	Apparent specific gravity	Bulk specific gravity	Hardness as to steel**	Pyrometric cone equivalent	Firing range (pyrometric cone)
D-1	05	C	6.59	35.08	1.23	2.25	8.92	12.54	13.19	0.95	25.59	2.61	1.94	SS	28	
	04	C	7.94	36.43	1.69	2.58	9.38	10.97	11.67	0.94	22.99	2.56	1.97	S		02 to
	01	C	11.68	40.17	3.67	3.75	11.36	8.06	8.76	0.92	17.87	2.48	2.04	S		13
	4	DC	13.07	41.56	4.23	4.18	11.92	6.29	6.99	0.90	14.54	2.43	2.08	S		
	8	C	14.29	42.78	4.44	4.54	12.13	4.87	5.47	0.89	11.43	2.36	2.09	HS		
	13	GB	18.04	46.53	5.20	5.68	12.89	2.11	3.10	0.68	6.79	2.36	2.19	HS		
D-2	05	LB	5.16	45.04	0.71	1.77	11.21	9.39	10.93	0.86	21.09	2.45	1.93	SS	below	
	04	B	9.26	49.14	1.65	3.20	12.15	8.26	9.61	0.86	19.32	2.49	2.01	SS	19	04 to
	01	BO	13.33	53.21	3.32	4.65	13.82	5.75	7.47	0.77	15.69	2.49	2.10	SS		8
	4	Br	13.03	52.91	3.68	4.54	14.18	4.74	6.32	0.75	13.21	2.41	2.09	S		(over-
	8	OBr	14.74	54.62	3.78	5.16	14.28	3.31	4.80	0.69	10.22	2.37	2.13	HS		fired
	13	Br	7.07	46.95	4.70	2.43	15.20	3.25	5.41	0.60	10.55	2.18	1.95	HS		at 13)
D-3	05	OBr	11.17	49.99	2.98	3.88	12.53	8.23	914	0.90	17.73	2.36	1.94	SS	below	04 to
	04	LBr	23.06	61.88	6.24	8.38	15.79	2.68	3.52	0.76	7.88	2.43	2.24	S	19	02
	01	Br	23.94	62.76	7.78	8.70	17.33	0.73	1.41	0.52	3.19	2.33	2.26	HS		
	4	DBr	24.17	69.22	8.29	8.82	17.84	0.81	1.25	0.65	2.84	2.34	2.27	HS		
D-4	05	C	6.89	37.64	1.46	2.36	8.58	13.12	13.88	0.95	26.51	2.60	1.91	SS		1 to
	04	C	8.62	39.37	2.18	2.95	9.30	11.88	12.51	0.95	24.39	2.58	1.95	SS	29	8
	01	C	12.85	43.60	3.83	4.50	11.05	8.43	9.07	0.93	18.41	2.49	2.03	HS		
	4	DC	14.51	45.26	4.28	5.09	11.40	5.93	6.59	0.90	13.64	2.40	2.07	HS		
	8	YB	16.07	46.82	4.89	5.68	12.01	3.82	3.58	0.83	9.09	2.32	2.11	HS		
	13	B	17.43	48.18	6.15	6.17	13.27	0.93	1.83	0.51	3.86	2.23	2.14	HS		
D-5	05	OBr	4.77	41.26	1.18	1.63	10.99	12.51	15.25	0.82	28.06	2.56	1.84	SS		
	04	Br	11.87	48.36	2.55	4.14	12.36	8.36	10.45	0.80	20.69	2.50	1.98	S	below	04 to
	01	Br	15.72	52.21	4.95	5.53	14.76	5.00	7.56	0.66	15.57	2.44	2.06	HS	19	5
	4	Br	16.84	53.33	5.43	5.95	15.24	4.29	6.71	0.64	14.02	2.43	2.09	HS		(over-
	8	Br	19.98	56.47	5.62	7.17	15.43	2.12	3.74	0.57	8.15	2.37	2.18	HS		fired
	13	Br	12.86+	23.63	8.40	4.50+	18.21	2.58	7.23	0.36	11.13	1.73	1.54	HS		at 13)

* Colors indicated as follows: (C) cream; (B) buff; (Br) brown; (G) gray; (O) orange; (Y) yellow; (I) ivory; (W) white; (P) pink; (D) dark; (L) light.
** Hardness indicated as follows: (SS) softer than steel; (S) steel hard; (HS) harder than steel.

TABLE 4.—Data on Ceramic Tests of Clays from the Wilcox Group (Continued)

Fired Properties

Sample number	Fired to cone	Fired color*	Volume shrinkage, per cent	Total volume shrinkage, per cent	Linear shrinkage (measured), per cent	Linear shrinkage (calculated), per cent	Total linear shrinkage, per cent	Absorption, cold water, per cent	Absorption, boiling water, per cent	Saturation coefficient	Apparent porosity, per cent	Apparent specific gravity	Bulk specific gravity	Hardness, as to steel**	Pyrometric cone equivalent	Firing range (pyrometric cone)
D-6	05	C	4.84	35.23	0.93	1.63	9.71	12.98	13.79	0.94	26.20	2.57	1.90	SS		
	04	I	8.08	38.47	1.47	2.78	10.25	10.88	11.83	0.92	23.31	2.57	1.97	SS	27	03 to
	01	LB	11.03	41.42	3.60	3.81	12.38	7.51	8.53	0.88	17.32	2.46	2.03	S		above
	4	DC	12.73	43.12	3.85	4.43	12.68	5.86	6.81	0.86	14.10	2.41	2.07	HS		8
	8	DC	13.73	44.12	4.21	4.79	12.99	4.41	5.19	0.85	10.90	2.36	2.10	HS		
	13	DB	16.50	46.89	5.39	5.83	14.17	2.72	3.62	0.75	7.82	2.34	2.16	HS		
D-7	05	LC	0.97	21.53	+0.53	0.33	6.10	17.39	19.86	0.88	33.56	2.54	1.69	SS		
	04	C	6.58	27.14	0.69	2.25	7.32	14.58	16.76	0.87	29.83	2.54	1.78	SS	26	6 to
	01	C	8.37	28.93	1.64	2.88	8.27	12.72	15.51	0.82	28.07	2.52	1.81	SS		above
	4	C	10.21	30.77	2.44	2.44	9.07	11.30	14.30	0.79	26.46	2.52	1.85	SS		13
	8	LB	12.20	32.76	2.95	4.24	9.58	8.94	12.41	0.72	23.45	2.47	1.89	SS		
	13	B	13.40	33.96	3.21	4.68	9.84	7.33	11.82	0.62	22.58	2.47	1.91	HS		
G-1	05	C	2.58	33.78	0.24	0.87	8.77	13.47	14.19	0.95	26.39	2.53	1.86	SS		
	04	I	4.30	35.50	0.43	1.46	8.96	12.20	12.98	0.94	24.53	2.50	1.89	SS	about	3 to
	01	LB	6.67	37.87	1.81	2.29	10.34	9.68	11.00	0.88	21.34	2.47	1.94	SS	23	above
	4	B	8.49	39.69	2.48	2.75	11.01	7.78	9.15	0.85	18.12	2.42	1.98	S		13
	8	B	9.46	40.66	2.17	3.07	10.70	6.11	8.23	0.82	16.46	2.39	2.00	HS		
	13	DB	12.65	43.85	3.87	4.06	12.40	4.49	5.84	0.77	12.09	2.35	2.07	HS		
G-2	05	C	1.04	15.68	+0.53	0.33	4.50	24.05	27.02	0.89	41.34	2.61	1.53	SS		
	04	LB	6.88	21.52	1.54	2.25	6.57	22.95	25.50	0.90	40.29	2.65	1.58	SS	27	6 to
	01	YB	17.88	32.52	5.50	5.64	10.53	14.80	17.83	0.83	31.38	2.56	1.76	SS		above
	4	B	18.76	33.40	5.40	5.90	10.43	12.93	16.58	0.78	29.35	2.51	1.77	SS		13
	8	B	20.28	34.92	5.76	6.36	10.79	11.72	15.38	0.76	27.84	2.51	1.81	S		
	13	B	22.52	37.16	6.22	7.00	11.25	10.24	14.10	0.73	26.23	2.52	1.86	HS		
G-3	05	LC	5.49	32.69	0.62	1.87	8.48	12.84	13.66	0.94	26.09	2.58	1.91	SS		
	04	LB	8.53	37.73	1.85	2.80	9.71	10.86	11.68	0.93	23.01	2.56	1.97	SS	about	02 to
	01	B	12.60	39.80	4.25	4.04	12.11	7.11	7.90	0.90	16.27	2.46	2.06	SS	20	6
	4	DB	16.23	43.43	5.13	5.13	12.99	4.18	4.92	0.85	10.53	2.39	2.14	S		(over
	8	DB	18.24	45.44	5.50	5.73	13.36	2.40	3.29	0.73	7.24	2.37	2.20	HS		fired
	13	DB	9.84	37.04	5.12	3.18	12.98	2.99	4.99	0.60	9.93	2.21	1.99	HS		at 13)

* Colors indicated as follows: (C) cream; (B) buff; (Br) brown; (G) gray ;(O) orange; (Y) yellow; (I) ivory; (W) white; (P) pink; (D) dark; (L) light.
** Hardness indicated as follows: (SS) softer than steel; (S) steel hard; (HS) harder than steel.

TABLE 4.—Data on Ceramic Tests of Clays from the Wilcox Group (Continued)

Fired Properties

Sample number	Fired to cone	Fired color*	Volume shrinkage, per cent	Total volume shrinkage, per cent	Linear shrinkage (measured), per cent	Linear shrinkage (calculated), per cent	Total linear shrinkage, per cent	Absorption, cold water, per cent	Absorption, boiling water, per cent	Saturation coefficient	Apparent porosity, per cent	Apparent specific gravity	Bulk specific gravity	Hardness, as to steel**	Pyrometric cone equivalent	Firing range (pyrometric cone)
G-4	05	IW	5.93	36.84	1.68	2.01	8.88	14.06	15.32	0.92	28.50	2.60	1.86	SS		
	04	I	12.16	43.07	1.66	3.91	8.86	10.27	11.29	0.91	22.35	2.55	1.98	S	26-27	03 to
	01	LB	16.61	47.52	4.83	5.25	11.03	5.15	6.21	0.83	12.98	2.40	2.09	HS		4
	4	LB	17.36	48.27	4.44	5.48	11.64	3.98	4.98	0.80	10.46	2.35	2.10	HS		
	8	YB	18.59	49.50	5.14	5.85	12.34	2.63	3.42	0.77	7.78	2.30	2.13	HS		
	13	DB	20.86	51.77	5.22	6.52	12.94	1.84	2.79	0.66	6.11	2.33	2.19	HS		
G-5	05	C	14.24	53.90	3.55	4.98	13.79	19.03	22.62	0.84	36.64	2.56	1.62	SS		
	04	LB	22.54	62.20	3.94	7.00	14.18	12.76	15.37	0.83	27.51	2.47	1.79	S	30	03 to
	01	YB	34.24	73.90	9.81	10.31	20.05	2.29	3.81	0.60	8.00	2.28	2.10	HS		01
HS-1	05	W	7.80	32.12	2.02	2.67	6.35	22.62	23.68	0.96	37.89	2.58	1.60	SS		
	04	W	12.97	37.29	2.26	4.54	6.59	19.90	20.95	0.95	35.41	2.62	1.69	SS	31-32	6 to
	01	W	22.29	46.61	4.31	8.07	8.64	11.87	13.19	0.90	24.93	2.52	1.89	S		10
	4	IW	25.01	49.33	6.24	9.14	10.57	9.59	11.28	0.85	22.11	2.52	1.96	HS		
	8	LC	27.65	51.97	6.99	10.25	11.32	6.97	8.40	0.83	17.05	2.45	2.03	HS		
	13	GC	33.57	57.89	8.12	12.76	12.45	1.37	2.29	0.60	5.04	2.32	2.20	HS		
HS-3	05	PW	5.60	24.06	1.62	1.90	5.15	19.13	20.35	0.94	35.00	2.65	1.72	SS		
	04	PW	9.34	27.80	1.70	3.20	5.25	16.79	18.25	0.92	32.67	2.66	1.79	SS	31	4 to
	01	IP	17.44	35.90	5.09	6.17	8.64	10.24	11.64	0.88	22.81	2.54	1.96	SS		8
	4	C	21.17	39.63	5.72	7.64	9.27	7.81	9.19	0.85	18.84	2.53	2.05	SS		
	8	C	26.57	45.03	7.21	9.80	10.86	2.91	3.59	0.81	7.90	2.39	2.20	HS		
	13	GW	30.19	48.65	8.26	11.29	11.50	0.52	0.69	0.75	1.59	2.35	2.31	HS		
HS-5	05	C	1.55	30.78	0.39	0.54	8.08	12.89	14.99	0.86	28.03	2.60	1.87	SS		
	04	C	2.50	31.73	0.94	0.84	8.63	11.76	14.00	0.84	26.32	2.55	1.88	SS	23	01 to
	01	B	3.73	32.96	2.08	1.25	9.77	9.75	12.83	0.76	24.38	2.51	1.90	SS		14
	4	B	4.96	33.92	2.49	1.70	10.18	8.59	11.77	0.73	22.72	2.50	1.93	S		
	8	LB	5.19	32.50	2.50	2.29	10.19	7.80	11.37	0.69	21.94	2.47	1.93	HS		
	13	B	6.98	36.21	2.86	2.39	10.55	6.48	10.70	0.61	21.08	2.50	1.97	HS		

* Colors indicated as follows: (C) cream; (B) buff; (Br) brown; (G) gray ;(O) orange; (Y) yellow; (I) ivory; (W) white; (P) pink; (D) dark; (L) light.
** Hardness indicated as follows: (SS) softer than steel; (S) steel hard; (HS) harder than steel.

TABLE 4.—Data on Ceramic Tests of Clays from the Wilcox Group (Continued)
Fired Properties

Sample number	Fired to cone	Fired color*	Volume shrinkage, per cent	Total volume shrinkage, per cent	Linear shrinkage (measured), per cent	Linear shrinkage (calculated), per cent	Total linear shrinkage, per cent	Absorption, cold water, per cent	Absorption, boiling water, per cent	Saturation coefficient	Apparent porosity, per cent	Apparent specific gravity	Bulk specific gravity	Hardness, as to steel**	Pyrometric cone equivalent	Firing range (pyrometric cone)
HS-6	05	W	4.50	20.53	0.75	1.52	5.23	17.75	18.30	0.97	32.21	2.60	1.76	SS		
	04	I	5.74	21.77	1.08	1.94	5.56	16.68	17.37	0.96	31.09	2.60	1.79	SS	31	5 to
	01	I	11.52	27.55	3.48	3.99	7.96	11.48	12.62	0.91	23.98	2.50	1.90	SS		9
	4	C	15.69	31.72	4.32	5.53	8.80	8.91	10.01	0.89	19.92	2.49	1.99	HS		
	8	C	22.24	38.27	5.91	8.03	9.39	4.35	5.06	0.86	10.93	2.42	2.16	HS		
	13	G	25.30	41.33	6.11	9.27	10.59	0.36	0.61	0.59	1.37	2.27	2.24	HS		
HS-7	05	PW	4.46	30.02	1.13	1.52	6.79	15.84	16.76	0.95	30.50	2.62	1.82	SS		
	04	I	6.02	31.58	1.18	2.04	6.84	14.36	15.28	0.94	28.42	2.60	1.86	SS	29	5 to
	01	C	9.79	35.35	2.89	3.38	8.55	10.83	12.17	0.89	23.49	2.52	1.93	SS		13
	4	C	12.49	38.05	3.95	4.35	9.61	8.99	10.45	0.86	20.80	2.51	1.99	HS		
	8	DC	13.33	38.89	4.05	4.65	9.71	6.86	8.26	0.83	16.60	2.41	2.01	HS		
	13	LB	18.47	44.03	5.63	6.59	11.29	3.66	4.58	0.80	9.76	2.36	2.13	HS		
HS-8	05	P	5.58	25.08	1.52	1.90	7.58	18.58	19.77	0.94	34.80	2.70	1.76	SS		
	04	P	7.49	26.96	1.47	2.57	7.53	16.47	17.52	0.94	31.71	2.65	1.81	SS	30-31	9 to
	01	PW	9.78	29.25	2.88	3.38	8.94	13.84	15.04	0.92	27.97	2.58	1.86	SS		above
	4	B	14.60	34.07	4.39	5.13	10.45	11.10	12.61	0.88	24.72	2.60	1.96	HS		13
	8	B	15.12	34.59	4.39	5.31	10.35	9.74	11.46	0.85	22.58	2.54	1.97	HS		
	13	B	18.63	38.10	5.51	6.63	11.57	6.51	8.92	0.73	18.38	2.52	2.06	HS		
HS-15	05	PW	2.32	25.82	0.53	0.77	6.59	12.84	13.38	0.96	25.15	2.51	1.88	SS		
	04	I	2.50	26.00	0.85	0.84	6.91	12.46	13.12	0.95	24.53	2.48	1.88	SS	23	9 to
	01	I	2.64	26.14	1.23	0.87	7.29	10.76	11.96	0.90	22.48	2.43	1.88	SS		above
	4	C	3.96	27.46	1.80	1.35	7.86	9.82	11.03	0.89	21.05	2.42	1.91	SS		13
	8	C	4.15	27.65	2.26	1.42	8.32	9.04	10.62	0.85	20.28	2.40	1.91	SS		
	13	B	6.70	30.20	2.41	2.29	8.47	6.78	9.09	0.75	17.82	2.38	1.96	HS		

* Colors indicated as follows: (B) buff; (Br) brown; (C) cream; (Gr) gray; (I) ivory; (O) orange; (P) pink; (W) white; (Y) yellow; (D) dark; (L) light.
** Hardness indicated as follows: (SS) softer than steel; (S) steel hard; (HS) harder than steel.

TABLE 4.—Data on Ceramic Tests of Clays from the Wilcox Group (Continued)
Fired Properties

Sample number	Fired to cone	Fired color*	Volume shrinkage, per cent	Total volume shrinkage, per cent	Linear shrinkage (measured), per cent	Linear shrinkage (calculated), per cent	Total linear shrinkage, per cent	Absorption, cold water, per cent	Absorption, boiling water, per cent	Saturation coefficient	Apparent porosity, per cent	Apparent specific gravity	Bulk specific gravity	Hardness, as to steel**	Pyrometric cone equivalent	Firing range (pyrometric cones)
M-1	05	C	0.71	19.82	0.23+	0.23	5.71	15.27	16.14	0.95	28.89	2.52	1.79	SS		
	01	C	1.72	20.83	1.12	0.57	7.06	14.32	15.88	0.90	28.90	2.56	1.82	SS	23	6 to
	5	B	6.33	25.14	1.81	2.15	7.75	10.93	12.71	0.86	24.15	2.51	1.90	HS		12
	8	GB	11.78	30.89	3.32	4.10	9.26	6.15	7.41	0.83	18.91	2.48	2.01	HS		
	12	IG	13.33	32.44	3.86	4.65	9.80	4.77	6.62	0.72	13.57	2.37	2.05	HS		
O-1	05	YC	6.83	50.78	2.28	2.32	12.70	14.03	15.37	0 91	28.13	2.55	1.83	SS		
	01	LY	16.04	59.99	5.02	5.65	15.44	9.44	10.38	0.91	20.86	2.54	2.01	HS	28	2 to
	5	LY	16.22	60.16	5.36	5.72	15.78	7.71	8.58	0.90	17.42	2.46	2.03	HS		7
	8	YG	17.59	61.54	5.94	6.25	16.36	4.64	5.55	0.84	11.49	2.34	2.07	HS		
	12	YG	19.88	63.83	7.03	7.13	17.45	2.55	3.69	0.69	7.82	2.30	2.12	HS		
O-2	05	W	0.10	11.07	0.15+	0.03	3.94	15.81	16.68	0.95	29.69	2.53	1.78	SS		
	01	W	3.22	14.19	0.94	1.08	4.78	14.39	15.34	0.94	28.07	2.54	1.83	SS	20	9 to
	5	CW	5.77	16.74	1.86	1.97	5.95	12.41	13.63	0.91	25.62	2.53	1.88	SS		12
	8	C	11.30	22.27	3.35	3.92	7.44	8.64	9.82	0.88	19.64	2.49	2.00	HS		
	12	GW	17.07	28.04	5.58	6.06	9.67	3.87	4.70	0.82	10.01	2.37	2.13	HS		
P-1	05	C	3.26	25.81	0.90	1.11	6.38	18.91	19.65	0.96	33.21	2.53	1.69	SS		
	01	C	12.36	34.91	4.20	4.32	9.68	13.83	14.51	0.95	27.13	2.57	1.87	S	20-23	3 to
	5	YC	21.15	43.70	6.75	7.64	12.23	7.41	7.89	0.94	16.41	2.49	2.08	HS		6
	8	YG	28.87	51.42	8.79	10.75	14.27	0.78	1.20	0.65	2.76	2.37	2.30	HS		
	12	LG	26.48	49.03	8.03	9.75	13.51	0.55	0.97	0.57	2.15	2.27	2.22	HS		

* Colors indicated as follows: (B) buff; (Br) brown; (C) cream; (G) gray; (I) ivory; (O) orange; (P) pink; (W) white; (Y) yellow; (D) dark; (L) light.
** Hardness indicated as follows: (SS) softer than steel; (S) steel hard; (HS) harder than steel.

Previously in this report only general categories of clay products, or the more commonly used, have been mentioned specifically. This procedure has been necessary because of the great variety of clay products manufactured, as can be seen from the following outline.

Types of Clay Products

- **Heavy clay products** (may be made from a great variety of clays, ranging from low-grade red-burning to high-grade buff-burning fire clay):
  - Structural
    - Common brick
    - Face brick (may be glazed)
    - Paving brick
    - Hollow tile
      - Back-up and partition tile
      - Facing and/or load-bearing tile
    - Quarry tile
    - Roofing tile (may be glazed)
    - Coping tile (usually salt glazed)
    - Terra cotta
  - Nonstructural
    - Drain tile
    - Sewer pipe (usually salt glazed)
    - Conduits (usually salt glazed)
    - Stoneware (salt glazed, slip glazed, or Bristol glazed)
    - Flower pots
- **Refractories** (made from clay capable of withstanding high temperatures, usually buff burning):
  - Standard nine-inch brick
  - Blocks and tiles
  - Other special shapes
  - } Includes light-weight insulating, as well as standard density shapes
- **Pottery** (made from red-firing clay and shale and from white to buff-firing fire clay):
  - All-clay
    - Stoneware
      - Domestic
      - Chemical
      - Electrical insulating
      - Art pottery
      - Kitchen and cooking ware
    - Earthenware
      - Art pottery
      - Kitchen and cooking ware
      - Flower pots
      - Garden pottery
- **Whiteware** (made from mixtures of ball clay, kaolin, feldspar, flint, etc. Usually contains less than 50 per cent ball clay):
  - Vitreous products
    - Porcelain tableware
    - China tableware
    - Hotel and restaurant china
    - Sanitary ware
  - Semivitreous products
    - Porcelain tableware
    - China tableware
    - Fine earthenware
    - Art ware
    - Majolica
  - Whiteware—Miscellaneous
    - Floor tile
    - Wall tile
    - Electrical fixtures
    - Refractory porcelain (usually vitrified)
    - Chemical porcelain (vitrified)
    - Technical products

Every product in the above list can be made from the clays listed in this report, with the exception of those that fire to a true red. This fact alone testifies adequately to the general usefulness of the clays.

The value of the clays of the Wilcox group in Arkansas for a number of ceramic uses is not a matter of speculation. Some of the clays tested for this report are being used for the manufacture of refractories and structural products and as ingredients in pottery bodies and vitrified sewer pipe.

Mather (1950) divides the Wilcox clays into three groups: ball clays, sagger clays and wad clays. This classification is commonly used, but should not be understood as excluding the clays from other types of use. The ball clays are usually very plastic fire clays of the intermediate or high heat duty class. They are characterized chiefly by low iron content and high plasticity and bond strength. If used as ball clays they are included as one ingredient, usually the principal one, of ceramic bodies to be used in the manufacture of whiteware, porcelain and the like. If used as a refractory clay a portion of the raw material is calcined clay, called grog, made from the same, or from some other type of more refractory clay. The additional ingredients may also include flint clays or alumina fines. Refractories that include ball clays or sagger clays in their composition are not ordinarily in the super-duty class, but are manufactured for installations subjected to only moderately high temperatures, but where high density and strength are more important than extreme resistance to heat.

The sagger clays are usually buff-firing and may or may not be less refractory than the ball clays. In fact, they are ball clays in all respects but fired color. They may be used in the manufacture of any refractory shape, but their use is necessarily limited by their resistance to elevated temperatures. The sagger clay is a plastic fire clay, and as a bond clay may be employed in minor amounts in the production of super duty or high heat duty refractory shapes.

Wad clays differ from the ball clays and sagger clays chiefly in that they are less pure, and less refractory. They are used as bond clays, and as a seal for kilns and saggers.

Some of the Wilcox clays are siliceous and have only moderate plasticity and bond strength. These clays cannot be properly placed in the above three classes, although they may be in some cases used for the same purposes.

In attempting to classify clays, even those as closely related as the Wilcox clays, it becomes apparent at once that no classification based on utilization is at all satisfactory. If correctly handled in the manufacturing processes any of the buff-firing clays of the Wilcox group could be used for the production of brick, hollow tile, sewer pipe, pottery, terra cotta, quarry tile, roofing tile, drain tile, conduits, flue liners, and flower pots. Many of them could be used in the manufacture of some type of refractory shape, or stoneware. A few of them are suitable for use in whiteware bodies and high class refractories.

Some of the lower grade clays are probably suitable for use in the manufacture of lightweight concrete aggregate. Sample No. D-3 is an example. The demand for lightweight aggregates is increasing rapidly, and in the near future may be an important branch of the ceramic industry, and if this is true may account for a relatively high proportion of clay utilization on a tonnage, if not a value basis.

Nothing has been said in the discussion of results of tests on individual clay samples of non-ceramic utilization of clay. The use of clays for fillers, diluents and extenders is quite important tonnage-wise. The higher grade clays are used in paper, oilcloth, rubber, and even confections. The demand for clays as carriers for insecticides has increased rapidly within the past few years due to the development of many new insecticides and fungicides together with an increasing knowledge of their usefulness. The desirable characteristics for insecticide carriers do not seem to be well defined by the manufacturers, but relatively small particle size, light color, and low cost seem to be clearly understood as qualifications. It is probable that many of the clays of the Wilcox group would be suitable for one or more of the non-ceramic uses of clay.

EFFECT OF CHEMICAL COMPOSITION ON CLAYS

Chemical analyses are available on six of the twenty-three clays tested by Plummer for ceramic properties. The chemical composition of these clays, given below in Table 5, necessarily reflects the mineral composition of the clays as previously discussed by Allen. The major differences are in the alumina to silica ratio. This in turn reflects, for the most part, the ratio of kaolinite to quartz. The iron oxide content, which is relatively low on all the samples analyzed, accounts for most of the differences in fired color, but the presence of varying amounts of titanium oxide tends to change the quality of the color produced by the iron, as does also the alumina-silica ratio and the particle size of both the clay and the quartz fractions.

The consistent presence of small percentages of both magnesium and potassium oxides suggests the presence of illite clay minerals, but this was not confirmed by either Allen or Grim as reported in the section on mineral composition (Chapter I). If montmorillonite is the clay mineral dominantly present other than kaolinite its presence in relatively large amounts doubtless accounts for the ceramic properties of some of the lower grade clays, such as Dallas county number D-3.

The total precentages of the fluxing oxides of magnesium and potassium correlate very well with the refractoriness of the clays (Table 2) with the exception of sample No. HS-15. The relatively low fusion point of this clay can be accounted for only by the high silica content, combined with fairly high percentages of fluxes.

TABLE 5

Chemical Composition of Six Selected Wilcox Clays

CLAY ANALYSES

Analyst: Troy W. Carney, Chemist, Division of Geology, Arkansas Resources and Development Commission.

Sample No.	D-7	G-1	HS 1	HS 6	HS 7	HS 15
Loss Ign.	6.21	5.88	11.65	7.23	7.54	7.10
SiO_2	73.0	72.5	57.2	65.5	68.8	73.6
Fe_2O_3	1.59	2.46	0.98	1.20	1.88	1.65
Al_2O_3	16.11	15.89	27.67	23.93	19.26	16.13
TiO_2	1.05	1.30	1.75	0.57	1.20	1.00
CaO	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.
MgO	0.55	0.73	0.46	0.32	0.52	0.48
K_2O	1.10	0.83	0.74	1.19	0.75	0.40
Na_2O	0.06	0.05	0.10	0.09	0.07	0.05
Totals	99.67	99.64	100.55	100.03	100.02	100.41

One of the nationally known ball clays, H. C. Spinks Clay Company's Champion and Challenger, is strikingly similar in chemical composition to the Hot Spring county sample No. HS-1. The Champion and Challenger ball clay is from the Grenada formation of the Wilcox group in West Tennessee. Parallel analyses are given below.

	SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	Na_2O	K_2O	TiO_2	Ign. loss
*Champion and Challenger	57.07	27.86	0.98	0.39	0.25	0.08	0.21	1.75	11.32
**Hot Spring county, HS-1	57.2	27.67	0.98	0.46	Tr.	0.10	0.74	1.75	11.65

* Company analysis reported by Whitlach (1940, p. 86).

**Analysis by Troy W. Carney, Division of Geology, Arkansas Resources & Development Commission.

No other parallels observed were as close as the above, but Paris Top White clay sold by the same company is quite close in chemical composition to the Hot Spring county sample No. HS-6. Whitlach (1940) reports a number of Tennessee clays from the Holly Springs formation of the Wilcox group that are quite similar to the more siliceous clays represented by samples No. D-7, G-1, and HS-15. A comparison of a number of siliceous fire clays found in Kansas in the Dakota formation of upper Cretaceous age to the siliceous fire clays of Arkansas, like those mentioned above, shows an even greater similarity in chemical composition and ceramic characteristics (Plummer and Romary, 1947).

CHAPTER III

CLAY LOCALITIES OF DALLAS COUNTY

General

The information on clay localities is drawn from several sources. All numbered samples, D-1, etc., are ones collected by the Division of Geology, and the corresponding ceramic reports were prepared by Mr. Plummer.

Unless otherwise stated in the text, all other data were collected by the State Mineral Survey, an organization financed by the Federal Works Progress Administration, and under the direction of the former Arkansas Geological Survey. Since most of the people employed by the State Mineral Survey were non-technical men their use of the terms clay and sand is hard to evaluate. However, the firing data obtained by this agency seems to be reliable and the men in charge of this phase, Mr. H. B. Grace and Mr. J. S. Lewis, Jr., were evidently qualified ceramists.

The present investigation included the examination of seven clay deposits in this county. The report of tests on these materials show that they are all buff burning clays, usually with wide firing ranges. Four of the clays can be classified as plastic fire clays. Sixty test holes dug by the State Mineral Survey encountered minable thicknesses of clay. The location of these holes is given and the log of each reported in the text. The State Mineral Survey also fired to low temperatures, clay from two test pits. In both cases the clays proved to be light colored on firing but further testing would be necessary to determine their possible use.

Tulip Area

Township 7 South, Range 15 West

Section 1

The logs of five test holes show that at least the north edge of the NW¼ is underlain at shallow depth by a promising deposit of gray to bluish clay which in turn is underlain in places by lignite. The thickness of the clay varies between 16 and 20 feet. The overburden consists of 2 to 5 feet of loam, sand and, in one hole, gravel. No information is available on the fired properties of the clay or on the north-south width of the deposit, but the thickness of the material and its plastic, non-sandy character, together with the fact that it is situated immediately adjacent to the railroad right-of-way makes it worthy of further examination.

Section 2

An auger hole in the center of the E½ NW¼ of this section encountered 22 feet of blue and gray clay. This material was overlain by 2 feet of soil and 5 feet of clay and gravel. The extent of this deposit cannot be estimated without further information. The only other available log in the section is of a hole three-eighths of a mile northwest where in 37 feet of section sampled, 23 feet was described as white clay. In this second hole most of the clay occurred as layers 1 to 2 feet thick, separated by sand layers of about the same thickness. Branner (1908) reports an exposure of 15 feet of clay resting on white sand in a gulley in the SW¼ NW¼. He reports that the lower 7 or 8 feet is white plastic clay of apparently fair quality. This deposit is within one mile of the railroad.

Section 6

An extensive deposit of clay is located along an east-west line through the center of the N½ of the section. For many years this clay was mined for pottery by William Byrd. Siebenthal (1891, p. 294-295) describes the deposit and gives the following chemical analysis of the weathered clay:

Silica	66.42 %
Alumina	21.19
Ferric oxide	1.956
Titanic oxide	1.02
Lime	1.13
Magnesia	.82
Soda	1.26
Potash	-------
Loss on ignition	7.76
Total	101.55 %
Sand in air-dried clay	37.28 %

According to Siebenthal, there was about 15 feet of light blue clay exposed in the pit. The clay had very little grit, was very plastic, but was difficult to dry without cracking. The logs of auger holes show that a clay lens 7 to 14 feet thick is encountered in 5 of the tests. The overburden consists of 1 to 1½ feet of soil and gravel.

The area was investigated by the writer in 1948. The color and other characteristics of the raw clay were observed to be as previously described. An auger sample of the unweathered clay was submitted for testing as number D-4; the ceramic report follows:

Sample No. D-4
Tested by Plummer

Plastic and Dry Properties

% Water of plasticity	27.28
% Shrinkage water	16.04
% Pore water	11.24
% Volume shrinkage	30.75
% Linear shrinkage (measured)	7.12
% Linear shrinkage (calculated)	9.35

Fired Properties

P.C.E.	cone 29					
Best firing range	cone 1 to cone 8					
Fired to cone	05	04	01	4	8	13
Fired color	cream	cream	cream	buff	buff	buff
Firing behavior	satisfactory at all temperatures					
% Volume shrinkage	6.89	8.62	12.85	14.51	16.07	17.43
% Total volume shrinkage	37.64	39.37	43.60	45.26	46.82	48.18
% Linear shrinkage (measured)	1.46	2.18	3.83	4.28	4.89	6.15
% Linear shrinkage (calculated)	2.36	2.95	4.50	5.09	5.68	6.17
% Total linear shrinkage	8.58	9.30	11.05	11.40	12.01	13.27
% Absorption 24 hours cold water	13.12	11.88	8.43	5.93	3.82	0.93
% Absorption 5 hours boiling water	13.88	12.51	9.07	6.59	3.58	1.83
Saturation Coefficient	0.95	0.95	0.93	0.90	0.83	0.51
% Apparent porosity	26.51	24.39	18.41	13.64	9.09	3.86
Apparent specific gravity	2.60	2.58	2.49	2.40	2.32	2.23
Bulk specific gravity	1.91	1.95	2.03	2.07	2.11	2.14
Hardness, as to steel	softer	softer	harder	harder	harder	harder

This is a gray plastic clay with good working properties. The test bricks showed a slight tendency to warp on one set of test bricks, but no warping occurred with the second set. As will be shown by the ceramic data given below, this clay has definite commercial possibilities.

According to the test data sample D-4 is a plastic fire clay suitable for intermediate heat duty service. Although the drying shrinkage is moderately high this property does not detract from the value of a clay that is used in the manufacture of fire brick, saggers and kiln furniture inasmuch as a large portion of the clay is grogged, or calcined before forming into final shapes. Plastic clays of this type have a high bond strength and can carry a high percentage of grog.

The clay is well suited to the manufacture of structural products such as brick and tile. The fired colors, ranging from cream to yellow buff, are pleasing. The firing range is long, and the lower limit of the firing range is low for a refractory clay, insuring fuel economy and ease in maintaining size tolerances. It might prove desirable to use some grog or sand with the clay because of the drying shrinkage and "fatness" of the clay.

Although this clay would be suitable for use in the manufacture of buff grades of earthenware and art pottery it probably would be rejected for use in stoneware because of the dark color at or near vitrification.

Section 9

An auger hole in the NW¼ SE¼ SE¼ penetrated 10 feet of brown clay with no overburden. About half a mile west of this hole 7 feet of semi-plastic sandy clay was found under 5 feet of gravel.

Section 10

The S½ S½ of the section is underlain by thick clay lenses associated with lignite. The three tests drilled encountered two heavy lenses of white to brown clay separated by a 2 to 3-foot bed of lignite. A total of 12 to 23 feet of clay was encountered in each of the holes with a maximum overburden of 4 feet of sand. The area is located about 3½ miles from the nearest railroad and is within a quarter of a mile of an all-weather road. This deposit should be more thoroughly examined.

Section 14

Two holes bored in the SE¼ NW¼ passed through 16 and 24 feet, respectively, of gray, plastic to semi-plastic, slightly sandy clay. The overburden consisted of 4 to 5 feet of sand. This locality is immediately adjacent to a public road and only 2 miles from the railroad. It would seem to merit further investigation both as to extent and fired characteristics of the clay.

Section 17

In the extreme southwest corner of the section, a drill hole encountered 14 feet of plastic clay that varied from white at the top to dark blue or gray at the bottom. The overburden totaled 7 feet, most of which was gravel.

Section 18

Four holes in the SE¼ of the section encountered from 8 to 15 feet of white plastic clay covered by 3 feet of soil and gravel. These holes, together with the one adjacent in section 17, could indicate a sizable body of clay. The area is crossed by State Highway 9 and is situated about 6 miles by road from two different rail lines. The deposit should be investigated more completely.

Section 20

One auger hole near the center of the SE¼ of the section passed through 15 feet of successively white, brown and blue clay that was semi-plastic and slightly sandy. It was covered by 4 feet of gravel. The area is situated close to all-weather roads and is about 6 miles from the railroad. It is possible that additional testing would reveal more clay.

Section 21

Ten feet of white clay under two feet of soil was encountered in a hole dug near the center of the W½ NW¼ of the section. In the extreme northeast corner of the section, 8 feet of white clay was underlain by 7 feet of brown clay; only 1 foot of overburden was present.

Section 30

In the SW¼ of the section, two holes were bored which had thick sections of white clay. The hole located in NE¼ NW¼ SW¼ had 7 feet of gray to white plastic clay separated from 8 feet of white non-plastic clay by a 3-foot bed of lignite. The hole, located about a quarter of a mile south of the first hole in W½ SE¼ SW¼, had a 14-foot section of gray plastic clay overlain by 4 feet of sand. This area is located adjacent to an all-weather road, about 6 miles from the railroad.

Section 31

A hole located near the center of the NW¼ encountered 5½ feet of blue to dark gray plastic clay underlain by lignite. There was 5 feet of overburden. Half a mile east of this hole another hole intersected a thickness of 7 feet of brown to gray plastic clay.

Section 32

Nine, fifteen, and twenty-two feet of clay are reported in the logs of three holes in the S½ of this section. Twenty-two feet of light to dark gray, plastic clay is reported from a hole in the center NW¼ SE¼. Three-eighths of a mile west of this hole, 15 feet of white sandy clay underlies 2 feet of soil. In the NW¼ SE¼ SW¼, about a quarter of a mile south of the second hole, 4 feet of white plastic clay which dries dark is separated from another 5 feet of white clay by a 2-foot bed of black earthy lignite. This last hole encountered 3 feet of overburden. The location of this area, adjacent to a road and within 6 miles of the railroad, is favorable. If the bed was proven to be sufficiently large and of a usable quality, it could be profitably developed.

Section 35

A test in SW¼ SE¼ NW¼ revealed 5 feet of clay under 1 foot of soil.

Willow Area

Township 7 South, Range 16 West

Section 5

The only clay encountered in the northern part of the township is in the southeast corner of this section where 6 feet of clay occurs under 2 feet of soil.

Section 15

The NE¼ of the section is underlain at three points by significant thicknesses of clay. The test in the center of the northwest forty was reported to have 19 feet of gray, very plastic clay. The holes in the center of the northeast and the southwest forties had 10 and 12 feet respectively of very sandy white clay. This area is crossed by an improved road and is situated within 2½ miles of the railroad. The result of incomplete tests on clay from this section is shown below. Since the fired color and working characteristics are satisfactory for some uses, it seems that further investigation of the area would be warranted.

State Mineral Survey Sample

Tested by Lewis

Plastic and Dry Properties		Fired Properties		
% Water of plasticity	28	Best firing range		cone 03
% Volume shrinkage	41.5	Fired to cone	03	
% Linear shrinkage (measured)	12.27	Fired color	cream	
		% Volume shrinkage	2.6	
		% Linear shrinkage (measured)	.87	
		% Absorption	12.6	
		% Apparent porosity	23.5	
		Apparent specific gravity	2.52	
		Bulk specific gravity	1.92	

Section 19

The log of a hole sunk in C W½ NE¼ reports 8½ feet of white clay, half a foot of rusty white clay and 4 feet of blue clay, with the hole still in clay when abandoned. The writer visited the locality with Mr. Foxhall during the present investigations. The clay was sampled with an auger to a depth of about 7 feet (D-1). The hole was bored at a point where the stream had removed the 3 to 5 feet of soil and gravel that covered the deposit elsewhere. The laboratory report on this material follows.

Sample No. D-1
Tested by Plummer

Plastic and Dry Properties

% Water of plasticity	25.46
% Shrinkage water	14.67
% Pore water	10.79
% Volume shrinkage	28.49
% Linear shrinkage (measured)	7.69
% Linear shrinkage (calculated)	8.72

Fired Properties

P.C.E.	cone 28					
Best firing range	cone 02 to cone 13					
Fired to cone	05	04	01	4	8	13
Fired color	cream	cream	cream	dark cream	cream	gray buff
Firing behavior	satisfactory, except slight warp at 13					
% volume shrinkage	6.59	7.94	11.68	13.07	14.29	18.04
% Total volume shrinkage	35.08	36.43	40.17	41.56	42.78	46.53
% Linear shrinkage (measured)	1.23	1.69	3.67	4.23	4.44	5.20
% Linear shrinkage (calculated)	2.25	2.58	3.75	4.18	4.54	5.68
% Total linear shrinkage (measured)	8.92	9.38	11.36	11.92	12.13	12.89
% Absorption 24 hours cold water	12.54	10.97	8.06	6.29	4.87	2.11
% Absorption 5 hours boiling water	13.19	11.67	8.76	6.99	5.47	3.10
Saturation Coefficient	0.95	0.94	0.92	0.90	0.89	0.68
% Apparent porosity	25.59	22.99	17.87	14.54	11.43	6.79
Apparent specific gravity	2.61	2.56	2.48	2.43	2.36	2.36
Bulk specific gravity	1.94	1.97	2.04	2.08	2.09	2.19
Hardness, as to steel	softer	as hard	as hard	as hard	harder	harder

This is a light gray, plastic clay, with good working properties. No difficulty was experienced in drying the small test bricks.

The physical properties combined with a pyrometric cone equivalent of cone 28 indicate that sample D-1 is a low heat duty plastic fire clay. Due to the fact that the limits of error in determining the P.C.E. of clays are likely to be one cone above or below that judged to be correct, it is possible that this clay has a P.C.E. of cone 29 or higher. In which case the classification would be changed to an intermediate heat duty fire clay.

In general the tests indicate that D-1 is an excellent clay. The shrinkage on drying is moderately high, and might necessitate the use of grog or sand in the manufacture of heavy clay products. Firing shrinkages are low, and increase slowly with increasing temperatures, indicating a long firing range. Although the saturation coefficient remains above 0.80 to above cone 8 the absorptions are reduced to about 8.0 per cent as low as cone 01, indicating good strength and durability for structural clay products at this low temperature. Although the firing range is given in the table as extending from cone 02 to cone 13, the practical range probably would be limited to between cone 1 and cone 8.

The clay would be suitable for use in a number of products, including low heat duty or intermediate heat duty refractories such as saggers and other kiln furniture, and fire bricks, art ware, earthenware and stoneware products, and structural clay wares. The clay is especially adaptable to use in structural clay products, such as brick and hollow tile.

Section 23

Twelve and one-half feet of clay was penetrated in a test hole located in the NEc SE¼ of the section.

Township 7 South, Range 17 West

Section 10

Siebenthal (1891, p. 304-305) records the occurrence of two beds of sandy kaolin in this township. The northernmost of these he designated as the Kilmer kaolin, as the exposure was on the property of J. R. Kilmer. He described it as being a slightly plastic, white clay, containing a great deal of rather coarse sand. It outcrops "in the bank of a drain" in the southeast quarter of the southeast quarter where a thickness of between 5 and 6 feet is exposed. The analysis of the washed kaolin given below (Siebenthal, 1891) shows that it has a high alumina content and only a moderate amount of iron and titanium oxide. There is a possibility that this deposit would merit further investigation.

Silica	52.269%
Alumina	32.207
Ferric oxide	1.781
Titanic oxide	1.505
Lime	.086
Magnesia	.028
Soda	.341
Potash	.271
Loss on ignition	11.170
Total	99.658%
Sand in air-dried clay	38.57 %

Section 26

A second sandy kaolin is located on Little Cypress Creek, in the SW¼ NE¼ of the section. Siebenthal (1891, pp. 302-304) described the section exposed in the bank of the creek as follows: "Drab sandy clay overlain by soil, etc., seven feet; ferruginous shaly sandstone, one-half foot; drab sandy clay as upper stratum, five feet; white sandy kaolin, six feet." When the writer visited this exposure with Mr. Foxhall, it was found to be essentially as previously described. The material was so sandy that it might easily be called clayey sand; it supported nearly vertical banks and even appeared as ledges in the bottom of the stream. This deposit should be examined more thoroughly and the firing characteristics and the economics of separating the kaolin from the sand should be determined. The analysis below shows that the washed clay has an abnormally low content of iron oxide and titanium oxide.

(Analysis from Siebenthal, 1891, p. 304)

Silica	62.166%
Alumina	26.096
Ferric oxide	.341
Titanic oxide	1.302
Lime	.051
Magnesia	Trace
Soda	.252
Potash	.364
Loss on ignition	9.067
Total	99.63 %
Sand in air-dried clay	67.94 %

Princeton Area

Township 8 South, Range 15 West

Section 3

There are several outcrops of gray clay along a small stream channel near the west line of the SE¼ of the section. At the point sampled (NW¼ SE¼) 6 feet of light gray, slightly silty clay (D-3) was overlain by gravelly soil up to 3 feet thick. The areal extent was not determined, but it possibly covered 40 acres or more since a drill hole in the center of the SW¼ is reported as having 7 feet of yellow to gray clay. The results of the firing tests are shown below.

The color of the unfired bricks made from sample D-3 was a very dark gray with a bluish tint. The clay is very plastic, but works well in hand molding, and like sample D-2 dries without cracking or warping despite the rather high drying shrinkage. In wares with a relatively large cross section some drying problems should be expected.

It is probable that this clay should not be considered as a possible ceramic raw material, especially in an area where high grade clays are plentiful. Sample D-3 is definitely a low grade clay. Drying shrinkages are excessive and the firing range is abnormally short. If circumstances warranted taking the trouble, this clay could be used for the manufacture of brick and tile, but only if a fairly high proportion of sand were mixed with the clay.

Sample No. D-3

Tested by Plummer

Plastic and Dry Properties

% Water of plasticity	35.41
% Shrinkage water	21.16
% Pore water	14.25
% Volume shrinkage	38.42
% Linear shrinkage (measured)	9.55
% Linear shrinkage (calculated)	11.54

Fired Properties

P.C.E.	below cone 19			
Best firing range	cone 04 to cone 02			
Fired to cone	05	04	01	4
Fired color	orange brown	light brown	brown	dark brown
Firing behavior	slight cracking and warping			
% Volume shrinkage	11.17	23.06	23.94	24.17
% Total volume shrinkage	49.99	61.88	62.76	69.22
% Linear shrinkage (measured)	2.98	6.24	7.78	8.29
% Linear shrinkage (calculated)	3.88	8.38	8.70	8.82
% Total linear shrinkage	12.53	15.79	17.33	17.84
% Absorption 24 hours cold water	8.23	2.68	0.73	0.81
% Absorption 5 hours boiling water	9.14	3.52	1.41	1.25
Saturation Coefficient	0.90	0.76	0.52	0.65
% Apparent porosity	17.73	7.88	3.19	2.84
Apparent specific gravity	2.36	2.43	2.33	2.34
Bulk specific gravity	1.94	2.24	2.26	2.27
Hardness, as to steel	softer	as hard	harder	harder

Section 4

In the bank of a small stream in the SW¼ NE¼ of the section there is an outcrop of light gray clay covered nearby by 2 to 3 feet of soil. During the present investigation, the deposit was sampled by an auger hole 6½ feet deep, the whole thickness being gray plastic clay (D-2). The laboratory report follows:

Sample D-2 is a light gray, plastic clay similar in appearance to sample D-1, but contrasting sharply with it in some of its ceramic properties. The clay is quite plastic, and works satisfactorily in hand molding, but tends to be sticky. Although the drying shrinkage is high, no cracking or warping was observed.

This clay is of the general type of plastic fire clays, but cannot be classed as a fire clay because the A.S.T.M. definition of refractories excludes all clays having a pyrometric cone equivalent below cone 19. The pottery industry probably would classify sample D-2 as a wad clay, indicating relatively dark fired color, low refractoriness, and high plastic and bonding properties.

Despite the fact that the drying shrinkage on this clay is rather high it probably has a wide range of usefulness. The fired colors range from a pleasing buff at low temperatures to an acceptable orange buff in the intermediate range. The firing range is moderately long, and at a rather low level. For use in heavy clay products such as brick and hollow tile it is probable that grog or sand would have to be added to prevent drying troubles. Firing temperatures for this class of product probably should be as low as the production of a sound product permitted. Cone 04 is the best temperature according to the test data.

Sample No. D-2

Tested by Plummer

Plastic and Dry Properties

% Water of plasticity	31.04
% Shrinkage water	20.66
% Pore water	10.38
% Volume shrinkage	39.88
% Linear shrinkage (measured)	10.50
% Linear shrinkage (calculated)	11.84

Fired Properties

P.C.E.	below cone 19					
Best firing range	cone 03 to cone 7 (overfired at 13)					
Fired to cone	05	04	01	4	8	13
Fired color	light buff	buff	buff & orange	orange brown	orange brown	pink brown
Firing behavior	satisfactory to cone 8					
% Volume shrinkage	5.16	9.26	13.33	13.03	14.74	7.07
% Total volume shrinkage	45.04	49.14	53.21	52.91	54.62	46.95
% Linear shrinkage (measured)	0.71	1.65	3.32	3.68	3.78	4.70
% Linear shrinkage (calculated)	1.77	3.20	4.65	4.54	5.16	2.43
% Total linear shrinkage (measured)	11.21	12.15	13.82	14.18	14.28	15.20
% Absorption 24 hours cold water	9.39	8.26	5.75	4.74	3.31	3.25
% Absorption 5 hours boiling water	10.93	9.61	7.47	6.32	4.80	5.41
Saturation Coefficient	0.86	0.86	0.77	0.75	0.69	0.60
% Apparent porosity	21.09	19.32	15.69	13.21	10.22	10.55
Apparent specific gravity	2.45	2.49	2.49	2.41	2.37	2.18
Bulk specific gravity	1.93	2.01	2.10	2.09	2.13	1.95
Hardness, as to steel	softer	softer	softer	as hard	harder	harder

Common earthenware pottery and art ware could be produced easily from this clay, but it is not suitable for use in making stoneware, owing to the fact it tends to bloat near vitrification, and the color is not suitable. The tendency to bloat suggests that it may be adaptable to the manufacture of lightweight concrete aggregate.

A hole drilled in the SWc SE¼ SW¼ of the section shows the following section: 5 feet, coarse, yellow and gray sand; 6 feet of gray clay with 5 per cent sand; 2 feet, soft dark brown lignite; 4 feet, light brown plastic; and 3 feet of brown clay and lignite. This 13-foot section of clay undoubtedly represents what Branner (1908, p. 74) referred to as the Butler clay, which he says is probably the first clay worked in Dallas County. It had not been used for many years when he examined the area prior to 1891. It is possible that this deposit will prove on examination to be extensive and with good enough fired qualities to be usable.

Less than half a mile north of the Butler deposit, in the N½ SW¼ of the section, is another clay deposit that Siebenthal (1891, p. 298) called Tall's clay. It is described as a light grayish, very plastic clay with a small quantity of coarse grit and some small lighter or white particles. The chemical analysis shown below seems to indicate that the clay warrants further testing.

(Analysis from Siebenthal, 1891, p. 298)

Silica	62.343%
Alumina	20.631
Ferric oxide	4.082
Titanic oxide	1.556
Lime	.173
Magnesia	.668
Soda	.325
Potash	.729
Loss on ignition	9.339
Total	99.846%
Sand in air-dried clay	16.73 %

Seven feet of gray clay with 5 per cent sand is also reported from near the center of the N½ NW¼ of the section.

Section 5

Green's clay, so called by Siebenthal (1891, pp. 297-298), is a deposit located in the SW¼ NW¼ of the section. A 10-foot exposure of light gray plastic clay is described. This clay has very little grit and when dry tends to cling to the tongue. The analysis shown below (Siebenthal, 1891), indicates the merit of more detailed study of the clay's fired properties.

Silica	68.03 %
Alumina	17.19
Ferric oxide	3.589
Titanic oxide	1.49
Lime	.81
Magnesia	1.00
Soda	.54
Potash	1.00
Loss on ignition	6.31
Total	99.959%
Sand in air-dried clay	35.80 %

A bed of clay 7 feet thick is reported in the W½ SW¼ SE¼ of the section. This clay is gray in color and reported to contain 10 to 15 per cent sand.

Section 6

A light blue clay in the SE¼ SW¼ of the section was once mined for pottery use. It was referred to by Siebenthal (1891, pp. 295-296) as the Welch clay. Because the clay fused at a lower temperature than common slip clay, it will not be discussed in detail. An analysis of the material is given below (Siebenthal, 1891). Two auger hole logs report 6 and 9 feet of gray, slightly sandy clay from the center of the NE¼ and from the SE¼ NE¼ SE¼ of the section. It is not known whether these clays from the east part of the section are superior to the Welch clay.

SiO	71.27%
A1O	16.86
FeO	2.14
TiO	1.75
CaO	.73
MgO	.77
NaO	.46
KO	.44
Ignition loss	6.54
Total	100.96%

Section 8

An eight-foot bed of light gray clay was found just below the surface in the center of the NE¼. Five feet of light brown, slightly sandy clay under four feet of overburden was encountered in the center of the SW¼ and 9 feet of white clay with 5 feet of overburden in the SE¼. It is not known whether these clays would make satisfactory fired bodies.

Section 11

A hole bored in the SE¼ NE¼ SW¼ encountered 14 feet of gray to brown clay without sand beneath 6 feet of overburden. Another hole located in the NW¼ NE¼ NW¼ of the section encountered 6 feet of slightly sandy clay at a depth of 3 feet.

Section 14

In the center of N½ NW¼, 16 feet of gray to brownish gray slightly sandy clay is covered by 8 feet of overburden.

Section 16

Twelve feet of gray to brown plastic clay was penetrated below 8 feet of coarse sand at a point near the center of the east line of the SE¼ of the section. A hole located in the NE¼ NW¼ NW¼ sampled 8 feet of similar clay below 6 feet of fine sand. This section is crossed by Highway 9 and is about 7 miles from the railroad. It is possible that these clays could be valuable.

Section 18

Only one log is available which shows minable thickness of clay in the section. This test was sunk in the NW¼ NE¼ NE¼ and encountered 9 feet of clay associated with an equal amount of lignite. The sample description from the surface down is: 6 feet of yellow, red, and gray coarse sand; 4 feet of gray clay, 2 per cent sand; 2 feet of brown clay, 2 per cent sand; 5 feet of black lignite. Since the clays associated with heavy lignite beds are frequently the best materials, it would be worthwhile to thoroughly investigate this deposit and the firing characteristics of these clays. The area is about 6 miles from the nearest railroad and is adjacent to all-weather roads.

Section 20

The Sullenbarger clay bed of Siebenthal (1891, pp. 296-297) occurs in the NE¼ of the section. It was described as an outcrop of 5 or 6 feet of dark sandy clay. The Lafayette Glass Company used the clay in 1870 and the ware is described as being thick and porous. The area is relatively inaccessible, so it was not re-sampled. It is possible that the material could be used for fired bodies.

Section 31

This locality is on the Princeton-Manning road, Highway 8. During the present sampling program, an auger hole was made near the outcrop of gray clay found on the north side of the road near the center of the section. Six feet of white to gray, slightly silty clay with reddish and brownish sandy streaks was encountered. The fired properties of the clay are included in the report shown below (D-5). A hole in the center of the SW¼ of the section encountered 8 feet of similar clay beneath 4 feet of overburden.

In the unfired state this clay is yellowish gray in color. It is quite plastic and the working qualities are good. No difficulty was experienced in drying the test bricks without warping or cracking, but due to the rather high shrinkage some warping may occur in drying heavier or longer pieces. Test data on ceramic properties are given below:

Sample D-5 is a rather low grade clay with a limited range of usefulness. The fired color serves to exclude it from any but the heavy clay products. The range of colors are varied and at some temperatures they are rather attractive. If there were a market for brick and tile in this color range the clay might be of interest to a manufacturer. Due to the high shrinkage on drying the addition of sand or grog would be advisable. Such addition probably would change the fired colors somewhat.

Sample No. D-5

Tested by Plummer

Plastic and Dry Properties

% Water of plasticity	33.65
% Shrinkage water	19.89
% Pore water	13.76
% Volume shrinkage	36.49
% Linear shrinkage (measured)	9.81
% Linear shrinkage (calculated)	10.91

Fired Properties

P.C.E.	below cone 19					
Best firing range	cone 04 to cone 5					
Fired to cone	05	04	01	4	8	13
Fired color	orange tan	golden brown	brown	rust brown	maroon	brown
Firing behavior	slight warping and cracking (overfired at 1)					
% Volume shrinkage	4.77	11.87	15.72	16.84	19.98	12.86
% Total volume shrinkage	41.26	48.36	52.21	53.33	56.47	23.63
% Linear shrinkage (measured)	1.18	2.55	4.95	5.43	5.62	8.40
% Linear shrinkage (calculated)	1.63	4.14	5.53	5.95	7.17	4.50
% Total linear shrinkage (measured)	10.99	12.36	14.76	15.24	15.43	18.21
% Absorption 24 hours cold water	12.51	8.36	5.00	4.29	2.12	2.58
% Absorption 5 hours boiling water	15.25	10.45	7.56	6.71	3.74	7.23
Saturation Coefficient	0.82	0.80	0.66	0.64	0.57	0.36
% Apparent porosity	28.06	20.69	15.57	14.02	8.15	11.13
Apparent specific gravity	2.56	2.50	2.44	2.43	2.37	1.73
Bulk specific gravity	1.84	1.98	2.06	2.09	2.18	1.54
Hardness, as to steel	softer	as hard	harder	harder	harder	harder

At cone 13 the test bricks were softened sufficiently to deform, and definite bloating occurred. Fired under the correct conditions sample D-5 could be expected to bloat sufficiently to produce a lightweight aggregate.

Township 8 South, Range 16 West

Section 5

The log of a hole in the center of the NE¼ of the section shows 8 feet of very slightly sandy, gray, plastic clay overlain by 6 feet of fine sand. The area is favorably situated for transportation if a sizable body of usable clay was proven by drilling and testing.

Section 12

In the center of the SW¼ of the section, there is an 8-foot bed of gray, plastic, non-sandy clay below 6 feet of coarse yellow and gray sand.

Section 13

Thirteen feet of stiff gray clay with 5 per cent of sand is reported to underlie 4 feet of clayey sand in the center of the NE¼ of the section. The thickness of this clay, when considered with that described from section 12, indicates that a workable body of clay may be present. The area is about 7 miles from the railroad and is located on a good road.

Manning Area

Township 8 South, Range 17 West

Section 15

During the present investigation, clay was sampled from a cut in the north side of State Highway 8, near the center of the section. The outcrop of clay was about 5 feet thick and extended east for about 100 feet where it became obscured by thickening overburden. To the east of the sample point the clay had been removed by a small stream. The surface evidence seemed to indicate that the deposit could extend over an area of 10 acres and possibly much more. The section at the point sampled is as follows: up to 2 feet of gray white sandy soil; 4 feet of sand, light straw-yellow in color; 5 feet of gray plastic clay drying to a gray white; 2 feet of gray clay with light chocolate colored seams at 3 to 6-inch intervals; the total thickness of clay was not penetrated. The results of tests performed on this clay are shown below (D-6).

The clay from this deposit is rather dark gray in the dry, unfired condition, but was a brownish gray after adding the tempering water. The clay is quite plastic and smooth and the working properties are good. Data on ceramic tests follow:

The clay represented by sample No. D-6 is a good quality low heat duty plastic fire clay suitable for a number of uses. In the field of pottery refractories it should make an excellent clay for saggers and other kiln furniture. In other types of refractory shapes its usefulness is limited only by the pyrometric cone equivalent of cone 27.

Although the relatively high drying shrinkage, typical of plastic fire clays in Arkansas and other areas, is a nuisance to the heavy clay products manufacturer he is able to produce satisfactory ware either by the addition of inert materials such as grog or sand, or by exercising extreme care in forming and drying.

On the whole the firing characteristics of sample No. D-6 seem to be very good. The fired colors ranging from ivory to dark buff are pleasing. The firing range extending from cone 03 to cone 8 for structural clay products is quite long. Although the saturation coefficient remains high throughout most of the firing range, absorptions, and probably fired strengths, compensate for this characteristic.

In addition to low heat duty refractories and structural products this clay would be suitable for use in earthenware pottery of certain types. It can be vitrified to a stoneware, but the color is rather dark.

Section 25

In the SW¼ SW¼ of the section, there is an exposure of approximately 80 feet of Wilcox sediments including several clay beds. This exposure is the site of a lignite pit which was operated during the late war by the American Dyewood Company. It is referred to locally as the "Manning Lignite Pit." Mr. H. B. Foxhall has described the exposure in the west end of the pit as follows:

10-20 feet buff to gray, fine grained sand; 8 inches soft clayey brown lignite; 2 feet grayish brown sandy clay; 1½-2 feet soft, brownish black lignite; 8-10 feet gray clayey silt (sample D-7); 7-8 feet hard black lignite.

A channel sample (D-7) was taken through the 10 feet of gray sandy to silty carbonaceous, foliated clay immediately overlying the basal lignite bed. The firing tests showed the material

Sample No. D-6

Tested by Plummer

Plastic and Dry Properties

% Water of plasticity	27.74
% Shrinkage water	15.76
% Pore water	11.98
% Volume shrinkage	30.39
% Linear shrinkage (measured)	8.78
% Linear shrinkage (calculated)	9.25

Fired Properties

P.C.E.	cone 27					
Best firing range	cone 03 to above cone 8					
Fired to cone	05	04	01	4	8	13
Fired color	cream	ivory	light buff	buff	buff	dark buff
Firing behavior	satisfactory at all temperatures					
% Volume shrinkage	4.48	8.08	11.03	12.73	13.73	16.50
% Total volume shrinkage	35.23	38.47	41.42	43.12	44.12	46.89
% Linear shrinkage (measured)	0.93	1.47	3.60	3.85	4.21	5.39
% Linear shrinkage (calculated)	1.63	2.78	3.81	4.43	4.79	5.83
% Total linear shrinkage (measured)	9.71	10.25	12.38	12.68	12.99	14.17
% Absorption 24 hours cold water	12.98	10.88	7.51	5.86	4.41	2.72
% Absorption 5 hours boiling water	13.79	11.83	8.53	6.81	5.19	3.62
Saturation Coefficient	0.94	0.92	0.88	0.86	0.85	0.75
% Apparent porosity	26.20	23.31	17.32	14.10	10.90	7.82
Apparent specific gravity	2.57	2.57	2.46	2.41	2.36	2.34
Bulk specific gravity	1.90	1.97	2.03	2.07	2.10	2.16
Hardness, as to steel	softer	softer	as hard	harder	harder	harder

to be unusually good. Since this deposit is located in the immediate vicinity of a railroad, it would be worthwhile to accurately outline the deposit and determine the thickness of overburden with the idea of it eventually being worked.

Before firing this clay is a gray tan when dry and a gray-brown when wet. The brown or tan color is probably due to organic materials inasmuch as the light colors of the fired clay preclude the presence of appreciable amounts of limonite which otherwise might account for the color. Like most of the clays tested for this report the clay from this deposit is plastic and smooth and has good working properties.

So far as the test data is indicative, this is a very good grade low heat duty plastic fire clay of the type often designated as sagger clay. Although limited for use as a refractory by the deformation temperature, or P.C.E., of cone 26 the clay deposit represented by sample No. D-7 is very well suited to use in the manufacture of structural products such as brick and tile. The drying shrinkage is moderate and firing shrinkages are relatively low. Although temperatures above cone 6 will be required for completely sound brick or tile, such temperatures are commonly used and not considered excessive. The firing range is fairly long, with small decreases in size as the firing temperatures are increased, thus insuring uniformity in the size of the finished product. The colors, ranging from cream to buff, are good throughout the range of the firing tests.

It is probable that a good grade of earthenware pottery or stoneware could be made from this clay, but the temperatures required for the production of this type of ware would be well above those commonly used.

Sample No. D-7
Tested by Plummer

Plastic and Dry Properties

% Water of plasticity	26.04
% Shrinkage water	11.85
% Pore water	14.19
% Volume shrinkage	20.56
% Linear shrinkage (measured)	6.63
% Linear shrinkage (calculated)	6.43

Fired Properties

P.C.E.	cone 26					
Best firing range	cone 6 to above 13					
Fired to cone	05	04	01	4	8	13
Fired color	light cream	cream	cream	cream	light buff	buff
Firing behavior	satisfactory at all temperatures					
% Volume shrinkage	0.97	6.58	8.37	10.21	12.20	13.40
% Total volume shrinkage	21.53	27.14	28.93	30.77	32.76	33.96
% Linear shrinkage (measured)	0.53+	0.69	1.64	2.44	2.95	3.21
% Linear shrinkage (calculated)	0.33	2.25	2.88	2.44	4.24	4.68
% Total linear shrinkage	6.10	7.32	8.27	9.07	9.58	9.84
% Absorption 24 hours cold water	17.39	14.58	12.72	11.30	8.94	7.33
% Absorption 5 hours boiling water	19.86	16.76	15.51	14.30	12.41	11.82
Saturation Coefficient	0.88	0.87	0.82	0.79	0.72	0.62
% Apparent porosity	33.56	29.83	28.07	26.46	23.45	22.58
Apparent specific gravity	2.54	2.54	2.52	2.52	2.47	2.47
Bulk specific gravity	1.69	1.78	1.81	1.85	1.89	1.91
Hardness, as to steel	softer	softer	softer	softer	softer	harder

State Mineral Survey Sample
Tested by Grace and Lewis

Plastic and Dry Properties

% Water of plasticity	39.4
% Volume shrinkage	40.7
% Linear shrinkage (measured)	12.05

Fired Properties

Best firing range	not determined	
Fired to cone	03	2
Fired color	white	white
% Volume shrinkage	10.1	12.5
% Linear shrinkage (measured)	3.49	4.35
% Absorption	17.1	16.4
% Apparent porosity	30.1	29.2
Apparent specific gravity	2.51	2.57
Bulk specific gravity	1.76	1.81

A sample of clay from this section was also tested by the State Mineral Survey, but the records do not show where, within the section, the pit was located. This was a plastic brown clay that fired white at cone 2, and in general it seemed to be a material with satisfactory characteristics.

Township 9 South, Range 16 West

Section 13

A test hole located near the center of the NE¼ went through 8 feet of gray, plastic clay containing 10 per cent sand. The clay was overlain by 7 feet of fine yellow and gray sand.

Section 18

Branner (1908, p. 84) reports the occurrence of 20 feet of white pipe clay underneath 8 feet of soil and gravel in a well in the NE¼ NE¼ of the section.

Township 9 South, Range 17 West

Section 1

According to Branner (1908, p. 84) a well dug in the SW¼ of the section encountered 15 feet of plastic clay in the bottom.

Section 35

Near the center of the NW¼ of the section there is a cut which is reported to have an exposure of 6 feet of clay underlain by 2 feet of white clay and sand.

CHAPTER IV

CLAY LOCALITIES OF GRANT COUNTY

General

The reports of ceramic tests on the five Grant County clays sampled during the current program and the 14 previously tested by the State Mineral Survey show that the area is rich in potentially valuable buff burning clays. Minable thicknesses of clay were encountered in 142 test holes sunk by the State Mineral Survey. How many of these additional deposits are of high grade clay is not known but with the clays tested showing the characteristics of low and intermediate heat duty fire clays it is safe to assume that others will be equally valuable.

Ico Area

Township 3 South, Range 13 West

Section 1

Thirteen feet of gray plastic clay containing approximately one per cent of sand underlain by 6 feet of brown clay with no sand was encountered in a test hole located in the center of the NE¼ of the section. Overburden consists of one foot of soil. If further tests show the deposit to have sufficient tonnage and that the clay is usable, as seems indicated, the location is favorable for operation of a pit. It is less than a quarter of a mile from U. S. Highway 167, approximately 15 miles from Little Rock, and about 8 miles from a railroad.

Section 2

Eight feet of white clay containing approximately 15 per cent sand is reported in a hole in the center of the northwest quarter of the section.

Section 3

Eight feet of white plastic clay containing about 20 per cent sand is exposed in the NW¼ NE¼ SW¼.

Section 11

Eight feet of plastic gray clay with 20 per cent sana and overlain by one foot of soil is reported from a test hole near the center of the NE¼ of the section.

Section 15

The greatest thickness of clay encountered in the township was in a test in the center of the NE¼ of this section. Beneath 4 feet of soil and surface clay, the auger penetrated a total of over 21 feet of gray, nonplastic clay. The upper 14 feet of this clay was reported to contain 1 per cent sand while the lower 7 feet contained about five per cent sand. The total thickness of lens was not determined. A hole sunk in the center of the SW¼ encountered 8 feet of clay beneath 8 feet of discolored clay. This deposit is located about 4 miles from a railroad and about 18 miles from Little Rock.

Section 19

Two test holes in the eastern half of the section encountered appreciable thicknesses of gray clay. In the NE¼ NE¼ 12½ feet of nonsandy clay was found beneath 6 inches of soil. A test hole in the NE¼ NW¼ SE¼ was reported to have 10½ feet of plastic, gray clay containing three per cent sand. Six inches of soil constituted the overburden.

Section 20

The eastern half of this section is shown, by two test holes, to be underlain in part by 10 feet of gray clay. The hole in the SW¼ NW¼ NE¼ showed only 1 foot of soil covering the clay. The second hole is located in the SW¼ SE¼ SE¼. In this hole the clay was overlain by 5 feet of sand and soil and the clay was reported to contain 2 per cent sand.

Section 21

Seven feet of non-plastic non-sandy clay, separated by 1 foot of red clay and sand from 4 feet of similar clay, was the sequence described from a hole in the NW¼ NE¼. The overburden totaled 3 feet and was composed of soil and red clay.

Section 27

At a point a few hundred feet west of the center of the SE¼ SE¼ a lens of gray plastic clay was penetrated. The thickness of the clay at this point was 8 feet. The overburden was 3 feet thick.

Section 28

Eleven feet of gray plastic clay was encountered beneath 1 foot of soil in a hole in the center of the SW¼ SW¼.

Section 29

It was reported that 8 feet of gray plastic clay was penetrated in a test located in the SE¼ SW¼ of the section.

Section 31

Two test holes in the eastern edge of the section encountered 11 to 12 feet of gray clay. The hole bored in the SE¼ NE¼ SE¼ showed a thickness of 11 feet of crumbly gray clay with 1 per cent sand. The gray clay was overlain by 4 feet of soil and yellow clay. The other test was located in the center of the E½ NE¼ of the section, approximately ½ mile north of the first hole. The clay lens at that point was 12 feet thick and the clay was plastic in character with about 2 per cent included sand. The overburden consisted of 2½ feet of soil and red clay. This locality is situated within ½ mile of a railroad and an all-weather road. It is about 1 mile east of Belfast.

Section 32

Seven feet of gray clay containing two per cent sand lies underneath a cover of 5 feet of soil and red clay. This locality is in the SW¼ NW¼ NW¼. Just north of the center of the south line of the SW¼ of the section, the following sequence was reported: soil and yellow clay, 3 feet; gray clay with five per cent sand, 6 feet; blue clay with two per cent sand, 4 feet; yellow sand and clay, 2 feet. In the center of the N½ NE¼ of the section a hole was drilled that encountered 13 feet of gray clay containing 10 per cent sand. The overburden here amounted to 2 feet.

Section 33

The log of hole bored near the center of the NW¼ of the section reports 9 feet of gray clay under 6 feet of soil and yellow clay. The clay was estimated to contain from two to five per cent sand.

Shaw Area

Township 3 South, Range 14 West

Section 21

In the center of the SW¼ SW¼ of the section a test encountered 11½ feet of gray plastic clay containing 1 to 5 per cent sand. A hole near the center of the NW¼ of the section had a thickness of 8½ feet of gray clay with 7 per cent sand. Half a mile east of the second hole, in the center of the NE¼, 6 feet of gray plastic clay was penetrated that contained from ½ to 2 per cent sand. The overburden in these holes varied from 6 inches to 3 feet in thickness.

Section 22

The greatest thickness of clay in this section was encountered in a hole located in the NW¼ NW¼ SE¼. The log of this hole recorded the following: soil, 6 inches; gray plastic clay containing ½ to 2½ per cent sand, 11 feet; brown clay, 6 inches; crumbly black dirt and lignite, 2 feet; brown non-plastic clay, 3 feet. The material in the lower part of this hole was evidently lignitic. A test bored in the center of the NW¼ encountered 5 feet of gray clay beneath 2 feet of soil and red clay. In the center of the S½ SE¼ SW¼ 6 feet of gray clay with 10 per cent sand was underlain by 1 foot of brown non-sandy clay. The overburden here is 5 feet thick. This section is crossed by a road and the deposits are located within about ½ mile of a railroad, making them easily accessible if otherwise of value.

The following ceramic report on material from one of these deposits indicates that it is satisfactory buff firing clay between cones 03 and 4.

State Mineral Survey Sample

Tested by Lewis

Plastic and Dry Properties		Fired Properties			
% Water of plasticity	31.6	Best firing range	cones 03 to 4		
% Volume shrinkage	35.3	Fired to cone	03	2	4
% Linear shrinkage (measured)	10.60	Fired color	buff	buff	brown
		% Volume shrinkage	5.8	5.6	5.4
		% Linear shrinkage (measured)	1.97	1.90	1.83
		% Absorption	19.1	18.6	16.0
		% Apparent porosity	32.7	32.0	25.8
		Apparent specific gravity	2.54	2.53	2.51
		Bulk specific gravity	1.71	1.72	1.79

Section 24

Twelve and one-half feet of very plastic, gray to brownish, non-sandy clay was penetrated near the center of the SE¼ of the section. The overburden at this point consisted of 4½ feet of soil and discolored clay. A test located in the NW¼ NW¼ NW¼ revealed 14 feet of gray plastic clay beneath one foot of soil. The clay was estimated to contain between 2 and 5 per cent sand.

Section 25

Eleven feet of gray clay with 5 per cent sand was found in a hole located 400 feet north of the center of the SE¼ of the section. One foot of soil covered the clay at a point near the center of the SW¼ of the section, 5 feet of gray clay containing 5 per cent sand is overlain by 5 feet of soil and sand.

Section 27

Six inches of soil occurs on top of 11½ feet of plastic gray clay in the NE¼ NW¼ NE¼. The clay is estimated to contain 5 per cent sand. In a hole near the center of the SW¼ of the section the following sequence of sediments was encountered: soil, 6 inches; red and gray clay, 2½ feet; gray plastic clay containing 2 per cent sand, 3 feet; yellow sand and clay, 1 foot; very plastic gray clay with one-half per cent sand, 8 feet; coarse gray sand, 2 feet.

Section 28

Eight feet of crumbly to plastic clay containing up to one-half per cent sand is reported from the center of the N½ SW¼ NW¼ of the section. The overburden totals 3 feet.

Section 29

A test hole in the NW¼ SE¼ NE¼ penetrated 8 feet of gray plastic clay. The clay was estimated to contain up to 2 per cent sand and is overlain by 2½ feet of soil and red clay.

Section 30

Six feet of gray plastic clay containing 10 per cent sand is reported from the center of the SE¼ SE¼. The overburden totals 4 feet.

Section 31

Four feet of overburden covers a 6-foot thickness of gray clay near the center of the NW¼ SE¼. The clay is reported to contain 5 per cent sand.

Section 32

Near the center of the N½ SE¼ NE¼, 9 feet of gray clay was penetrated. This clay contains up to 10 per cent sand.

Section 33

Two holes bored in the NE¼ of the section encountered 9 feet of gray clay with 1 foot of overburden. These holes are located in the center of the SW¼ NE¼ and in the center of the S½ NE¼ NE¼. A hole located in the SW¼ SE¼ NE¼ encountered 7 feet of gray to brown clay beneath 2 feet of overburden. These holes are within 4 miles of the railroad and located adjacent to state Highway No. 35.

Section 34

Over 10 feet of gray clay containing 5 per cent sand is found under 2 feet of soil and red clay at a point 100 yards west of the center of the NE¼ of the section.

Section 35

At a point 200 feet east of the center of the N½ SW¼ a test hole encountered 12½ feet of gray plastic clay beneath 2½ feet of soil and red clay. The clay contained up to 5 per cent sand.

Section 36

Six feet of gray clay followed by 5 feet of brown clay was penetrated in a test located near the center of the SW¼ of the section. The overburden consisted of 1 foot of yellow clay.

Township 3 South, Range 15 West

Section 35

Two tests in the NE¼ of the section encountered 11 and 13 feet of blue and gray clay. In the center of the NW¼ SE¼ NE¼ 11 feet of blue clay is overlain by 9 feet of soil and discolored clay. Thirteen feet of gray clay with 1 per cent sand is found below 3 feet of overburden 100 feet south of the center of the north line of the NW¼ NE¼. This area is cut by an all-weather road and is situated about 3 miles from the railroad.

Sheridan Area

Township 4 South, Range 13 West

Section 5

The log of a test hole bored near the center of the east line of the SE¼ NE¼ reports 10 feet of gray plastic clay with 2 per cent sand. Laboratory tests performed on clay from this section showed it to be a good buff firing material. The location within the section was not recorded for the fired sample. The area is within 1 mile of a railroad and crossed by roads. If a sizable deposit of clay could be located in the area, fired characteristics and availability of the clay would make the operation of a pit profitable after a market was established.

State Mineral Survey Sample

Tested by Grace and Lewis

Plastic and Dry Properties	
% Water of plasticity	27.8
% Volume shrinkage	23.5
% Linear shrinkage (measured)	7.29

Fired Properties			
Best firing range	not determined		
Fired to cone	03	2	4
Fired color	buff	buff	buff
% Volume shrinkage	2.7	1.5	5.7
% Linear shrinkage (measured)	.91	.51	1.94
% Absorption	17.6	17.4	14.3
% Apparent porosity	29.6	29.3	25.6
Apparent specific gravity	2.41	2.40	2.41
Bulk specific gravity	1.68	1.69	1.79

Section 7

Ten feet of gray plastic clay with 3 per cent sand is reported in a drill hole near the center of the SE¼ of the section.

Belfast Area
Township 4 South, Range 14 West

Section 1

A test hole bored near the center of the N½ SE¼ NE¼ encountered 11 feet of plastic gray clay with occasional yellow streaks in the upper 4 feet. The sand content was estimated to be 3 per cent; the overburden was reported to total 4 feet.

Section 3

Fourteen feet of gray to brown clay with 2 to 5 per cent sand was penetrated in a test located in the NE¼ NE¼ NE¼.

Section 5

Near the center of the SE¼ SE¼ a test hole encountered the following sequence: soil, 1 foot; brown plastic clay, 3 feet; gray non-plastic clay containing 5 per cent sand, 9 feet.

Section 6

Over 13 feet of plastic gray clay underlies the center of the south line of the SE¼ of the section. This clay is separated into an upper 4-foot layer and a lower 9-foot layer by a 6-foot bed of fine gray sand.

Section 7

An exposure and test hole located just south of the center of the NE¼ SE¼ showed a thickness of 10 feet of plastic gray clay underlain by 2 feet of crumbly brown clay. The gray clay contained approximately 5 per cent sand and the brown clay 10 per cent. Eight feet of plastic gray clay with 2 per cent sand is found below 1 foot of soil, 3 feet of similar clay, and 3 feet of sandy clay. This hole is located just north of the center of the south line of the SW¼ SW¼.

Section 8

In the SW¼ SW¼ NW¼ an exposure and test hole showed the following sequence of sediments to be present: soil, 1 foot; red sandy clay, 2 feet; plastic gray clay with 5 per cent sand, 7 feet; crumbly brown clay, 2 feet; gray plastic clay with 5 per cent sand, 9 feet. In the NE¼ NE¼ SW¼ there is a thickness of at least 9 feet of plastic gray clay with 5 per cent sand which is overlain by 4 feet of soil and red sandy clay. A test in the SW¼ NE¼ SE¼ showed the presence of 10 feet of gray plastic clay with a sand content of approximately 2 per cent and only 1 foot of overburden. The results of ceramic tests on material from this section show the presence of a good cream firing clay. The area is bordered by a road and the distance to the nearest railroad is about 5 miles.

State Mineral Survey Sample

Tested by Lewis

Plastic and Dry Properties	
% Water of plasticity	33.2
% Volume shrinkage	25.1
% Linear shrinkage (measured)	7.72

Fired Properties			
Best firing range	not determined		
Fired to cone	04	2	4
Fired color	cream	cream	cream
% Volume shrinkage	0.5	1.3	2.4
% Linear shrinkage (measured)	.17	.44	.81
% Absorption	23.4	22.5	22.5
% Apparent porosity	37.0	36.0	36.2
Apparent specific gravity	2.46	2.49	2.53
Bulk specific gravity	1.56	1.60	1.64

Section 11

Over 12 feet of gray clay with 15 per cent sand occurs at a point near the center of the NE¼ NW¼ SE¼.

Section 14

A test hole in the center of the SW¼ NE¼ was still in gray plastic clay after penetrating 11 feet of it. The clay was estimated to contain 2 per cent sand and was observed to have 3 feet of overburden at the point sampled.

Section 15

The following sequence of sediments was reported from a hole bored 100 yards south of the center of the SE¼ of the section: soil, 1 foot; red and gray crumbly clay with 10 per cent sand, 1 foot; gray, plastic to crumbly clay, 5 feet; light brown powdery clay, 1 foot; dark brown crumbly clay, 8 feet; fine white sand, 6 inches.

Section 16

Sixteen feet of gray plastic clay with 5 per cent sand is encountered approximately 100 yards south of the center of the SE¼ NW¼. There is 4 feet of overburden present. A light gray sandy clay was fired that came from this section, and it proved to be a satisfactory buff burning material.

State Mineral Survey Sample

Tested by Lewis

Plastic and Dry Properties		Fired Properties			
% Water of plasticity	34.2	Best firing range	not determined		
% Volume shrinkage	50.0	Fired to cone	04	03	2
% Linear shrinkage (measured)	14.47	Fired color	buff	buff	buff
		% Volume shrinkage	6.3	10.7	8.0
		% Linear shrinkage (measured)	2.15	3.70	2.74
		% Absorption	10.2	17.3	10.2
		% Apparent porosity	20.3	30.9	20.0
		Apparent specific gravity	2.41	2.60	2.43
		Bulk specific gravity	1.92	1.79	1.95

Section 17

A test hole in the SW¼ SW¼ SW¼ passed through 13 feet of clay that varied in character from plastic to crumbly and which contained from 2 to 10 per cent sand. The overburden totaled 1 foot.

Section 19

Nine feet of plastic gray clay containing about 3 per cent sand is reported from the NE¼ SE¼ NE¼. There is 1 foot of overburden at the point tested.

Section 24

Seven feet of gray plastic clay was encountered beneath 4 feet of overburden in a hole located in the center of the S½ SW¼ SW¼.

Section 25

A hole bored at a point near the center of the S½ NW¼ SE¼ cut through 8 feet of gray plastic clay which contained 5 per cent sand. The overburden was 1 foot thick.

Section 30

The following section was encountered in a hole in the center of the S½ SW¼ NW¼: soil, 1 foot; plastic gray clay containing approximately 20 per cent sand, 4 feet; plastic clay, gray to dark gray in color and containing 10 per cent sand, 7 feet.

Section 31

In the SW$\frac{1}{4}$ SE$\frac{1}{4}$ SE$\frac{1}{4}$ a total thickness of 14 feet of gray and brown plastic clay is encountered. This clay has about 10 per cent included sand and 3 feet of overburden. In a road cut east of a gravel pit $\frac{1}{2}$ mile north of the auger hole described above, there is reported to be an exposure of 23 feet of clay with very little silt. A sample from this last locality proved to be a satisfactory buff burning clay as shown by the report below. This exposure is located in the SW$\frac{1}{4}$ NE$\frac{1}{4}$ of the section 5$\frac{1}{2}$ miles by all-weather road to the railroad.

State Mineral Survey Sample

Tested by Grace and Lewis

Plastic and Dry Properties		Fired Properties			
% Water of plasticity	35.6	Best firing range	not determined		
% Volume shrinkage	53.8	Fired to cone	04	2	4
% Linear shrinkage (measured)	15.4	Fired color	buff	buff	buff
		% Volume shrinkage	1.6	3.6	6.1
		% Linear shrinkage (measured)	.54	1.22	2.08
		% Absorption	11.6	11.4	9.2
		% Apparent porosity	22.0	22.1	18.2
		Apparent specific gravity	2.45	2.51	2.42
		Bulk specific gravity	1.91	1.95	1.99

Section 35

Ten feet of gray clay estimated to contain 5 per cent sand was encountered in a hole located near the center of the NW$\frac{1}{4}$ SW$\frac{1}{4}$.

Section 36

A test pit dug on a hill in the SW$\frac{1}{4}$ NE$\frac{1}{4}$ SW$\frac{1}{4}$ went through 17 feet of gray to brown non-plastic clay. The sample of this clay tested fired red and cracked. If the sample was a representative one, the deposit is of no value in the ceramic industry. Another sample from the section fired to a red color at cone 04 without cracking and would be satisfactory for some uses.

Nydia Area

Township 4 South, Range 15 West

Section 13

In the SE$\frac{1}{4}$ NW$\frac{1}{4}$ NW$\frac{1}{4}$ of the section, there is a body of gray clay over 13 feet thick. The upper 6 feet is plastic and is estimated to contain 5 per cent sand; the lower 7 feet penetrated is crumbly and contains up to 2 per cent sand. A test near the base of the south slope of the hill crossed by the "Burnett Road," NE$\frac{1}{4}$ SW$\frac{1}{4}$ NE$\frac{1}{4}$, encountered 10 feet of plastic clay. The upper 4 feet was gray in color and contained about 2 per cent sand, while the lower 6 feet was brown, lignitic, and non-sandy. The laboratory report shown below is on a sample from this point. It indicates that the clay tested is a buff firing clay of satisfactory green and fired characteristics. The area is reached by an all-weather road, making it possible to reach the railroad after about a 7-mile haul.

State Mineral Survey Sample
Tested by Grace and Lewis

Plastic and Dry Properties		Fired Properties			
% Water of plasticity	37.6	Best firing range	not determined		
% Volume shrinkage	33.0	Fired to cone	04	2	4
% Linear shrinkage (measured)	9.97	Fired color	buff	buff	buff
		% Volume shrinkage	3.8	7.1	13.9
		% Linear shrinkage (measured)	1.28	2.43	4.87
		% Absorption	20.6	18.4	13.6
		% Apparent porosity	33.1	31.0	24.6
		Apparent specific gravity	2.39	2.77	2.33
		Bulk specific gravity	1.60	1.68	1.79

Section 18

The only information available on the clay in this section is the laboratory report below, which shows it to be material which merits further examination. The area is within 1 mile of the railroad but is not crossed by roads and, therefore, is difficult to investigate and more complicated to develop.

State Mineral Survey Sample
Tested by Lewis

Plastic and Dry Properties		Fired Properties			
% Water of plasticity	31.0	Best firing range	not determined		
% Volume shrinkage	32.4	Fired to cone	04	2	4
% Linear shrinkage (measured)	9.81	Fired color	white	white	cream
		% Volume shrinkage	2.2	2.5	4.8
		% Linear shrinkage (measured)	.74	.84	1.63
		% Absorption	15.6	15.7	14.2
		% Apparent porosity	27.7	28.2	26.2
		Apparent specific gravity	2.50	2.50	2.50
		Bulk specific gravity	1.80	1.79	1.85

Section 26

Over 8 feet of gray crumbly clay with 15 per cent sand was penetrated in a hole near the center of the NE¼ SE¼. Six feet of overburden was encountered.

Section 35

In the center of the S½ NE¼ NE¼ 7 feet of gray clay was encountered beneath 1 foot of soil. The clay had brown spots and was estimated to contain 10 per cent sand.

Prattsville Area

Township 5 South, Range 14 West

Section 1

A hole bored at a point near the center of the section went through 7 feet of sticky gray clay containing about 10 per cent sand. The overburden was 1 foot thick.

Section 2

Fifteen feet of gray, plastic to crumbly clay was penetrated in a hole in the NW¼ SW¼ NE¼. The clay contained about 5 per cent sand and was covered by 1 foot of soil.

Section 3

In the SE¼ NW¼ SW¼, 9 feet of gray clay was encountered below 7 feet of overburden. The clay was described as being crumbly and containing about 5 per cent sand.

Section 6

The following sequence of sediments was encountered in a test bored near the center of the SW¼ SW¼: soil, 1 foot; rocky material, 3 feet; gray plastic clay with about 5 per cent sand, 4 feet; very fine gray sand, 2 feet; gray plastic clay containing 3 per cent sand, 8 feet.

Section 7

Eleven feet of gray clay with 5 per cent sand was reported from a hole in the S½ SW¼ NW¼. One foot of overburden was recorded.

Section 9

In the NW¼ SW¼ there is a thickness of 8 feet of gray crumbly clay under 8 feet of gravel. The clay contains 2 per cent sand.

Fifteen feet of plastic clay was penetrated in a hole located in the SW¼ SE¼ NE¼. The overburden is 7 feet thick. The upper 2 feet of the clay is described as brown in color with 2 per cent sand. The lower 13 feet of clay is gray in color and contains about 5 per cent sand.

Section 16

An auger hole near the center of the SE¼ NW¼ encountered 12 feet of gray plastic clay containing 5 per cent sand. The overburden was 5 feet thick.

Section 31

Eleven feet of brown and gray clay with 10 per cent sand is overlain by 1 foot of soil, near the center of the NW¼ NW¼.

Poyen Area

Township 5 South, Range 15 West

Section 2

A hole bored in the center of the SE¼ NW¼ SW¼ passed through 11 feet of brown clay containing 15 per cent sand. The clay was covered at this point by 1 foot of soil.

Section 11

Nine feet of brown clay with 5 per cent sand was found in a hole near the center of the N½ SE¼ SE¼. Two feet of soil makes up the overburden at this point.

Section 12

In the center of the N½ NW¼ SE¼ a test hole penetrated 7 feet of gray plastic clay containing 2 per cent sand.

Section 17

One foot of soil covers 6 feet of gray clay containing 10 per cent sand in the SE¼ NW¼ SE¼.

Section 19

The following sequence of sediments was encountered in a test hole located near the center of the south line of the NE¼ SE¼: soil, 1 foot; fine white sand, 7 feet; gray clay with yellow streaks, 2 feet; brown clay with 2 per cent included sand, 6 feet; gray plastic clay with 10 per cent sand, 5 feet.

Section 24

Nine feet of brown plastic clay containing 10 per cent sand is found under a 1-foot soil mantle in the center of the W½ SE¼.

Section 28

A thickness of 13 feet of gray plastic clay is found at the center of the W½ E½. The clay is said to contain 5 per cent sand and is overlain at this point by 5 feet of soil, sand and clay.

Section 30

At a point near the center of the NW¼ NE¼, the following sequence was reported from a drill hole: soil, 1 foot; red clay with yellow streaks, 5 feet; gray sticky clay, 10 per cent sand, 2 feet; plastic to crumbly gray clay with 5 per cent sand, 10 feet.

Leola Area

Township 6 South, Range 14 West

Section 31

Two beds of plastic clay were sampled in this section by the writer. The first of these (G-1), located in the NE¼ NW¼, is exposed in a pasture about 50 yards west of the road. The sampled face consisted of 4 feet of gray plastic to silty clay overlain by 2 feet of sandy soil. A second exposure, in a road cut near the center of the section, showed 3½ feet of gray sandy to silty clay with occasional iron stains. This face was sampled (G-3) but the total thickness of the deposit was not determined.

The raw clay as represented by sample No. G-1 is light gray in color, and is somewhat above the average in plasticity. The working properties are good, although there is a slight tendency for the clay to be sticky. On half of the test bricks some warping was noted after drying, but the warp was not noticeable after firing, indicating that the tendency to warp is not serious. Data on ceramic properties are tabulated below.

Sample No. G-1

Tested by Plummer

Plastic and Dry Properties

% Water of plasticity	27.19
% Shrinkage water	16.35
% Pore water	10.84
% Volume shrinkage	31.20
% Linear shrinkage (measured)	8.53
% Linear shrinkage (calculated)	9.48

Fired Properties

P.C.E.	about cone 23					
Best firing range	cone 3 to above cone 13					
Fired to cone	05	04	01	4	8	13
Fired color	cream	ivory	light buff	buff	buff	dark buff
Firing behavior	satisfactory throughout test range					
% Volume shrinkage	2.58	4.30	6.67	8.49	9.46	12.65
% Total volume shrinkage	33.78	35.50	37.87	39.69	40.66	43.85
% Linear shrinkage (measured)	0.24	0.43	1.81	2.48	2.17	3.87
% Linear shrinkage (calculated)	0.87	1.46	2.29	2.75	3.07	4.06
% Total linear shrinkage	8.77	8.96	10.34	11.01	10.70	12.40
% Absorption 24 hours cold water	13.47	12.20	9.68	7.78	6.11	4.49
% Absorption 5 hours boiling water	14.19	12.98	11.00	9.15	8.23	5.84
Saturation Coefficient	0.95	0.94	0.88	0.85	0.82	0.77
% Apparent porosity	26.39	24.53	21.34	18.12	16.46	12.09
Apparent specific gravity	2.53	2.50	2.47	2.42	2.39	2.35
Bulk specific gravity	1.86	1.89	1.94	1.98	2.00	2.07
Hardness, as to steel	softer	softer	softer	as hard	harder	harder

Clay No. G-1 is a low heat duty fire clay, and should be considered a plastic fire clay because of its physical properties, despite the fact that the chemical analysis shows it to be rather siliceous. As a refractory this clay would be limited in its usefulness to saggers and other kiln furniture and similar low heat duty applications.

Its ceramic properties indicate that this clay should be especially suitable for use in the manufacture of brick and tile, and other heavy clay products. Although the drying shrinkage is somewhat high the clay seems to be fairly open and to dry without undue care. This characteristic is probably due to a rather high content of finely divided quartz.

The saturation coefficient remains high over most of the firing range, but the cold water absorption is reduced to about 8.0 per cent around cone 3, or possibly cone 4, indicating that brick or tile manufactured from the clay and fired to this temperature, or higher, would withstand severe weather conditions. The fired colors are good, ranging from light to dark buff between cone 4 and cone 13.

Firing shrinkages are low, and dimensions change slowly with increase of temperature, a characteristic favorable to uniformity of size in the finished product.

Although this clay could be used for buff earthenware there is likely to be little use of it for this purpose because of the availability of lighter firing and lower temperature clays in Arkansas.

Sample No. G-3
Tested by Plummer

Plastic and Dry Properties

% Water of plasticity	26.40
% Shrinkage water	14.23
% Pore water	12.17
% Volume shrinkage	27.20
% Linear shrinkage (measured)	7.86
% Linear shrinkage (calculated)	8.36

Fired Properties

P.C.E.	about cone 20					
Best firing range	cone 02 to cone 6, or lower					
Fired to cone	05	04	01	4	8	13
Fired color	light buff	light buff	rather dk. buff	dark buff	dark buff	grayed dk. buff
Firing behavior	satisfactory to cone 8; overfired at 13?					
% Volume shrinkage	5.49	8.53	12.60	16.23	18.24	9.84
% Total volume shrinkage	32.69	37.73	39.80	43.43	45.44	37.04
% Linear shrinkage (measured)	0.62	1.85	4.25	5.13	5.50	5.12
% Linear shrinkage (calculated)	1.87	2.80	4.04	5.13	5.73	3.18
% Total linear shrinkage	8.48	9.71	12.11	12.99	13.36	12.98
% Absorption 24 hours cold water	12.84	10.86	7.11	4.18	2.40	2.99
% Absorption 5 hours boiling water	13.66	11.68	7.90	4.92	3.29	4.99
Saturation Coefficient	0.94	0.93	0.90	0.85	0.73	0.60
% Apparent porosity	26.09	23.01	16.27	10.53	7.24	9.93
Apparent specific gravity	2.58	2.56	2.46	2.39	2.37	2.21
Bulk specific gravity	1.91	1.97	2.06	2.14	2.20	1.99
Hardness, as to steel	softer	softer	softer	as hard	harder	harder

This is a plastic clay with good working properties. No cracking or warping occurred in drying the test bricks, although the drying shrinkage is rather high. The unfired color of the clay is between tan and gray.

In the nomenclature of pottery industries G-3 would be designated a wad clay. It is a plastic clay, rather dark in fired color, and not very refractory. Like many of the less refractory buff-firing clays its most obvious use would be in the manufacture of brick and tile, and other heavy clay products. Drying shrinkage is moderately high, but firing shrinkages are only average. No particular difficulties should be experienced in manufacturing brick and tile from this clay. The fired colors are attractive, especially in the lower part of the firing range. Its chief advantage is that it can be fired to a relatively low temperature and still produce sound ware. If service conditions were not too severe good brick possibly could be produced by firing as low as cone 05.

Due to its low maturing temperature this clay would be a possible raw material for some types of pottery such as art ware. Vitrification was not reached in the tests, but there is a probability that stoneware could be manufactured from this clay by firing to a temperature above cone 8 and below cone 13, where some overfiring occurs.

State Mineral Survey Sample
Tested by Lewis

Plastic and Dry Properties	
% Water of plasticity	34.1
% Volume shrinkage	41.0
% Linear shrinkage (measured)	12.13

Fired Properties			
Best firing range	not determined		
Fired to cone	03	2	4
Fired color	white	white	buff
% Volume shrinkage	5.4	6.8	18.6
% Linear shrinkage (measured)	1.84	2.32	6.63
% Absorption	16.4	15.2	6.5
% Apparent porosity	29.4	27.6	13.5
Apparent specific gravity	2.53	2.51	2.44
Bulk specific gravity	1.79	1.82	2.07

Township 6 South, Range 15 West

Section 3

Two hundred feet west of the center of the NW¼ SW¼, 12 feet of gray clay was encountered which had 3 per cent sand. The overburden amounted to 8½ feet.

Section 5

Eight feet of brown plastic clay is overlain by 6 feet of sand and clay near the center of the W½ NW¼ NE¼. The clay is estimated to contain 5 per cent sand.

Section 6

Laboratory tests showed that two samples of clay from somewhere in this section were excellent white firing material. At five points in the area, clay beds were found which varied from 8 to 28 feet in thickness. The thickest section is exposed in the center of the NE¼ SE¼, where the following sequence is described: soil, 1 foot; yellow crumbly sandy clay, 4 feet; non-plastic gray clay, 12 feet; non-plastic brown clay containing 1 per cent sand, 12 feet; gray non-plastic clay with 5 per cent sand, 4 feet. Approximately a quarter of a mile west of this locality, near the center of the NW¼ SE¼ the following section was encountered in a drill hole: soil, 1 foot; gravel 3 feet; gray clay with 1 per cent sand, 2 feet; slightly brownish gray clay, 12 feet; yellowish streaked, brown clay, 6 feet. In a hole located in the SE¼ NE¼ NW¼, 22 feet of brown to dark brown clay was encountered below a 2-foot thickness of gray plastic clay. Eight feet of gray plastic clay is found under 1 foot of soil in the SE¼ SE¼ and in the SW¼ SW¼, 16 feet of gray plastic clay is reported to lie under 6 feet of overburden. There are no roads in the section but a road touching the southeast corner that would make it a 3-mile haul from this point to the railroad. From all the available information it seems that workable quantities of white firing clays are present in the area.

State Mineral Survey Sample
Tested by Lewis

Plastic and Dry Properties		Fired Properties			
% Water of plasticity	20.7	Best firing range	not determined		
% Volume shrinkage	15.7	Fired to cone	03	2	4
% Linear shrinkage (measured)	4.98	Fired color	white	white	white
		% Volume shrinkage	1.6	.7	1.2
		% Linear shrinkage (measured)	.54	.24	.40
		% Absorption	16.5	15.8	15.1
		% Apparent porosity	29.8	28.8	28.0
		Apparent specific gravity	2.55	2.53	2.56
		Bulk specific gravity	1.79	1.81	1.94

State Mineral Survey Sample
Tested by Lewis

Plastic and Dry Properties		Fired Properties	
% Water of plasticity	34.2	Best firing range	Not determined
% Volume shrinkage	39.1	Fired to cone	4
% Linear shrinkage (measured)	11.63	Fired color	white
		% Volume shrinkage	2.2
		% Linear shrinkage (measured)	.74
		% Absorption	12.3
		% Apparent porosity	20.0
		Apparent specific gravity	1.74
		Bulk specific gravity	1.39

Section 8

In the NE¼ NE¼ SE¼ two exposures are described as having 47 and 19 feet of gray and brown clay. The following is a description of the east-west exposure: gray, friable slightly plastic clay containing 2 per cent sand, 30 feet; vari-colored sandstone, clay and sand, 2 feet; plastic, sticky gray clay with 2 per cent sand, 8 feet; dark brown lignitic-like clay, 1 foot; chocolate brown, slightly plastic clay, 9 feet. The north-south exposure situated near the west end of the above exposure is described as showing 1 foot of soil; red and yellow sandy clay, 5 feet; brown plastic clay with 5 per cent sand, 4 feet; plastic chocolate-brown clay, 15 feet. The thickness of these clay bodies seems to warrant their further investigation.

Section 13

A hole bored in the SW¼ SW¼ SW¼ encountered 19 feet of gray plastic clay containing 1 per cent sand. The overburden totaled 5 feet. About half a mile east near the center of the W½ SW¼ SE¼, 9 feet of gray plastic clay containing 10 to 20 per cent sand was penetrated after passing through 5 feet of overburden.

Section 18

Ten feet of gray and brown clay containing up to 5 per cent sand is encountered under 5 feet of overburden in the center of the south line of the SW¼ SW¼. In the NE¼ SW¼ SE¼, 9 feet of gray clay and 2 feet of brown clay are covered by 4 feet of overburden.

Section 20

Near the center of the S½ SW¼ NW¼ there is a 12-foot thickness of gray clay containing 2 per cent sand. It is overlain by 2 feet of soil and red clay at the point sampled.

Section 23

Eleven feet of gray clay with 1 to 5 per cent sand occurs below 4 feet of overburden in the NE¼ NE¼ NE¼. Half a mile south of this locality 20 feet of gray clay containing 2 per cent sand was penetrated. Here the deposit is reported by Waggoner (1941) as covering several acres in this section and extending over a similar area in section 24. The sample whose fired characteristics are given below was taken from a pit dug in the roadside on the north side of a valley. The clay outcrops on both sides of the valley which at this point is about 100 yards wide. This area is less than half a mile from the railroad and, from the available information, seems to be an excellent location for a source of buff firing clay.

State Mineral Survey Sample

Tested by Lewis

Plastic and Dry Properties	
% Water of plasticity	29.0
% Volume shrinkage	39.0
% Linear shrinkage (measured)	11.60

Fired Properties			
Best firing range		not determined	
Fired to cone	04	2	4
Fired color	buff	buff	buff
% Volume shrinkage	5.3	4.1	10.2
% Linear shrinkage (measured)	1.80	1.39	3.52
% Absorption	10.5	12.2	7.2
% Apparent porosity	20.3	23.1	14.5
Apparent specific gravity	2.43	2.46	2.36
Bulk specific gravity	1.93	1.89	1.96

Section 24

There is an exposure of sand and clay in a road cut on Highway 46, half a mile northeast of Leola, in the NW¼ SW¼. The writer sampled the clay and recorded the following sequence of sediments: yellowish gray to light gray fine sand, 5 feet; light gray fine sand with yellow streaks, 1 foot; light purple plastic clay with dark reddish brown streaks of carbonaceous material, gradually becoming lighter gray and showing occasional yellow stains and some sand with depth, 7 feet. The laboratory report on this clay is included below as sample G-4.

The plasticity of this clay is above the average, but except for some stickiness the workability is good. Consistent with both the plasticity and the stickiness, there is some tendency to warp on drying. The raw clay is grayish tan in color. It is moderately soft and slakes fairly rapidly in water.

Sample No. G-4 is a low heat duty plastic fire clay. In respect to plasticity, probable bonding properties, shrinkage, and low porosity at relatively low temperatures it should be classed as a ball clay. Some would object to the classification on the basis of fired color, which is darker than most commercially produced ball clays. With this single exception it would serve all the purposes of a ball clay.

As a refractory clay for use in the manufacture of saggers and other kiln furniture it should be considered a high quality material. Due to the rather high drying shrinkage a fairly large proportion of grog should be used

Sample No. G-4

Tested by Plummer

Plastic and Dry Properties

% Water of plasticity	28.73
% Shrinkage water	16.40
% Pore water	12.33
% Volume shrinkage	30.91
% Linear shrinkage (measured)	7.20
% Linear shrinkage (calculated)	9.36

Fired Properties

P.C.E.	cone 26-27					
Best firing range	cone 03 to cone 4					
Fired to cone	05	04	01	4	8	13
Fired color	ivory	ivory	light buff	light buff	buff	dark buff
Firing behavior	O.K. to cone 01; slight warp cone 4 to 13					
% Volume shrinkage	5.93	12.16	16.61	17.36	18.59	20.86
% Total volume shrinkage	36.84	43.07	47.52	48.27	49.50	51.77
% Linear shrinkage (measured)	1.68	1.66	4.83	4.44	5.14	5.22
% Linear shrinkage (calculated)	2.01	3.91	5.25	5.48	5.85	6.52
% Total linear shrinkage (measured)	8.88	8.86	11.03	11.64	12.34	12.94
% Absorption 24 hours cold water	14.06	10.27	5.15	3.98	2.63	1.84
% Absorption 5 hours boiling water	15.32	11.29	6.21	4.98	3.42	2.79
Saturation Coefficient	0.92	0.91	0.83	0.80	0.77	0.66
% Apparent porosity	28.50	22.35	12.98	10.46	7.78	6.11
Apparent specific gravity	2.60	2.55	2.40	2.35	2.30	2.33
Bulk specific gravity	1.86	1.98	2.09	2.10	2.13	2.19
Hardness, as to steel	softer	as hard	harder	harder	harder	harder

in forming. Other types of low heat duty refractories could equally well be made from this clay, and possibly could well be combined with a more refractory grog to produce an intermediate heat duty refractory such as fire brick. Due to its high bond strength a large proportion of grog could be used.

This clay is also suitable for the manufacture of brick and tile and other heavy clay products. Probably it would be advisable to grog the clay or to add sand for stiff mud extrusion, due to the tendency to warp and the rather high drying shrinkage. Firing temperatures could be relatively low, although the addition of grog or sand would slightly increase the maturing temperature. Such additions would have advantages in firing, however, because it would correct the objectionable feature of rapid change in size with increasing temperatures in the lower portion of the firing range.

A sample of clay from the NW¼ SE¼ of the section was tested and proved to be a satisfactory material that fired to a cream color. The following is a report of its physical characteristics.

State Mineral Survey Sample
Tested by Lewis

Plastic and Dry Properties	
% Water of plasticity	24.3
% Volume shrinkage	32.0
% Linear shrinkage (measured)	9.76

Fired Properties		
Best firing range		not determined
Fired to cone	2	4
Fired color	cream	cream
% Volume shrinkage	.4	5.8
% Linear shrinkage (measured)	.13	1.97
% Absorption	11.5	8.9
% Apparent porosity	21.2	17.6
Apparent specific gravity	2.37	2.43
Bulk specific gravity	1.86	1.96

Section 25

In the NW¼ SW¼ there is a total thickness of 23 feet of gray and brown clay containing from 1 to 5 per cent sand. The overburden is 5 feet thick. A hole in the SW¼ SW¼ penetrated 8 feet of gray clay which contained 5 per cent sand and was overlain by 1 foot of soil. Seventeen feet of brown and gray clay layers overlain by 1 foot of soil and containing from 2 to 5 per cent sand was reported from a test hole in the center of the SE¼. The writer sampled an outcrop occurring on the north side of the Leola-Carthage road, in the NE¼ SE¼. The character of the material outcropping was very similar to that examined in section 24, about 1 mile north. Underneath 3 to 4 feet of red, yellow and gray sand and sandy soil was a layer of fissile purple lignitic clay 6 inches to 1 foot in thickness. This was underlain by 18 inches of light gray plastic clay which in turn rested on 18 feet of clayey lignite and purple clay. The bottom foot was a hard sandy gray clay. Below are the reports on the fired characteristics of the purple lignitic clay (G-5) and the gray plastic clay (G-2) from this exposure.

Before grinding and mixing with water this clay was a mottled brown and tan color. It is a plastic clay with good working characteristics. A certain amount of graininess that did not prove to be particularly helpful in hand molding probably would be an advantage in stiff mud extrusion. The results of ceramic tests are given below.

The test data indicates that G-2 is a low heat duty plastic fire clay. The pyrometric cone equivalent of cone 27 is only two cones below the lower limits for an intermediate heat duty fire clay. Taking this into consideration together with its stability at cone 13 the clay appears to be a fairly good refractory suitable for a number of uses such as saggers and kiln furniture, and for other refractories not subjected to temperatures above those encountered in commercial kiln firing.

Clay No. G-2 appears to be slightly better than No. G-1 for the manufacture of structural clay products. Although the firing range is over a higher level it is apparently equally long, and it has the added advantage of a lower drying shrinkage. Firing shrinkages are somewhat higher for clay No. G-2, but they are not excessive, and the decrease in size is very gradual over the temperature range. The firing range of cone 6 to above cone 13 is estimated from the saturation coefficient. If in commercial manufacturing the saturation coefficient proved to be somewhat higher it would be necessary to fire to higher temperatures.

It will be noted that the bulk specific gravity remains relatively low, even at cone 13. This is considered an advantage in structural products in that it reduces the total tonnage of clay that must be handled.

Although this clay could be used in the manufacture of some types of pottery the firing temperatures probably would be considered excessive for that purpose.

Sample No. G-2
Tested by Plummer

Plastic and Dry Properties

% Water of plasticity	27.59
% Shrinkage water	9.00
% Pore water	18.59
% Volume shrinkage	14.64
% Linear shrinkage (measured)	5.03
% Linear shrinkage (calculated)	4.67

Fired Properties

P.C.E.	cone 27					
Best firing range	cone 6 to above cone 13					
Fired to cone	05	04	01	4	8	13
Fired color	cream	light buff	yellow buff	buff	buff	buff
Firing behavior	satisfactory over entire temperature range					
% Volume shrinkage	1.04	6.88	17.88	18.76	20.28	22.52
% Total volume shrinkage	15.68	21.52	32.52	33.40	34.92	37.16
% Linear shrinkage (measured)	0.53+	1.54	5.50	5.40	5.76	6.22
% Linear shrinkage (calculated)	0.33	2.25	5.64	5.90	6.36	7.00
% Total linear shrinkage	4.50	6.57	10.53	10.43	10.79	11.25
% Absorption 24 hours cold water	24.05	22.95	14.80	12.93	11.72	10.24
% Absorption 5 hours boiling water	27.02	25.50	17.83	16.58	15.38	14.10
Saturation Coefficient	0.89	0.90	0.83	0.78	0.76	0.73
% Apparent porosity	41.34	40.29	31.38	29.35	27.84	26.23
Apparent specific gravity	2.61	2.65	2.56	2.51	2.51	2.52
Bulk specific gravity	1.53	1.58	1.76	1.77	1.81	1.86
Hardness, as to steel	softer	softer	softer	softer	as hard	harder

Sample No. G-5
Tested by Plummer

Plastic and Dry Properties

% Water of plasticity	46.30
% Shrinkage water	25.28
% Pore water	21.02
% Volume shrinkage	39.66
% Linear shrinkage (measured)	10.24
% Linear shrinkage (calculated)	11.79

Fired Properties

P.C.E.	cone 30		
Best firing range	cone 03 to cone 01		
Fired to cone	05	04	01
Fired color	cream	light buff	yellow buff
Firing behavior	satisfactory		
% Volume shrinkage	14.24	22.54	34.24
% Total volume shrinkage	53.90	62.20	73.90
% Linear shrinkage (measured)	3.55	3.94	9.81
% Linear shrinkage (calculated)	4.98	7.00	10.31
% Total linear shrinkage	13.79	14.18	20.05
% Absorption 24 hours cold water	19.03	12.76	2.29
% Absorption 5 hours boiling water	22.62	15.37	3.81
Saturation Coefficient	0.84	0.83	0.60
% Apparent porosity	36.64	27.51	8.00
Apparent specific gravity	2.56	2.47	2.28
Bulk specific gravity	1.62	1.79	2.10
Hardness, as to steel	softer	as hard	harder

Despite the fact that this clay is highly plastic and somewhat sticky the working properties are fairly good. The unfired clay is pinkish brown in color, probably due to the presence of lignite. A relatively high percentage of organic compounds can also be inferred from the unusually high water of plasticity. Some warping and cracking occurred on drying as is to be expected in a clay having an abnormally high water of plasticity and drying shrinkage. From the above properties we may also infer that the clay mineral content is high and the particle size unusually small. Ceramic data follows:

Sample No. G-5 is a highly plastic intermediate heat duty fire clay with the general physical properties of a ball clay. The fired color is too dark for acceptance in the whiteware industry, but the clay has possible usefulness, where the requirements are less rigorous, as a refractory bond clay.

With a pyrometric cone less than two cones below the minimum requirement for a high heat duty refractory it is probable that minor additions of a more refractory grog, or clay, would bring the P.C.E. up to the intermediate heat duty class. But even without being fortified this clay should have a considerable range of usefulness as a refractory for use in the manufacture of saggers, and other intermediate heat duty refractories.

Owing to the high shrinkages and relatively short firing range this clay would require the addition of grog calcined from the same deposit, or of sand, to make it suitable for use in the manufacture of structural clay products. But with the addition of such materials it should make a very good brick or tile.

Section 26

Seven feet of brown plastic clay containing 1 per cent sand is found under 1 foot of soil in the SE¼ SW¼ SW¼.

Section 27

In the SW¼ SE¼ NW¼ of the section a test hole encountered 11 feet of gray plastic clay containing 2 to 5 per cent sand. There was 1 foot of overburden.

Section 28

Four feet of overburden covers 13 feet of gray clay near the center of the W½ SW¼ NE¼. The clay is estimated to contain 10 per cent sand. In the SE¼ NW¼ SE¼ of the section 15 feet of gray plastic clay containing 2 to 5 per cent sand occurs beneath 1 foot of soil. An exposure in the SE¼ SW¼ is described as having 13 feet of gray plastic clay lying under 4 feet of overburden. The clay contains approximately 2 per cent sand.

Section 29

A test hole located in the SE¼ NW¼ NW¼ encountered 6 feet of gray plastic clay under 4 feet of overburden.

Section 31

Ten feet of clay was encountered at two places in the section. An exposure in the NW¼ NE¼ SE¼ had 10 feet of brown clay containing 2 to 5 per cent sand covered by 6 feet of overburden. In the SW¼ SE¼ SW¼ 10 feet of gray clay was encountered beneath 1 foot of soil. This clay was estimated to include 2 to 3 per cent sand.

Section 33

A clay deposit believed to be of commercial size is located in the NE¼ NE¼, about 2 miles west of Leola on Highway 46. The section exposed is described as follows: gravel, 1 foot; gray clay, 3 feet; white clay, 5 feet; gray clay, 2 feet; white clay, 8½ feet; a total of 18½ feet. This body of plastic, siliceous, light gray clay apparently continues into the adjacent part of section 34.

Section 34

In the center of the W½ NW¼ 9 feet of gray clay containing 5 per cent sand is encountered below 1 foot of soil. This is believed to be part of the same lens which is found in adjacent parts of section 33. Nine and one-half feet of gray clay is found in the NW¼ NE¼ SE¼. It contains between 2 and 5 per cent sand and is overlain by 6 inches of soil.

Section 35

A test hole located in the center of the NE¼ SE¼ passed through 10 feet of gray plastic clay without finding the bottom of the lens. The clay containing 15 per cent sand. In the SW¼ SW¼ SW¼ 8 feet of gray clay containing 5 per cent sand lies beneath 1 foot of soil.

CHAPTER V

CLAY LOCALITIES OF HOT SPRING COUNTY

General

Hot Spring is the northernmost county, covered by this report, in which clays of Wilcox age are mined. Two companies, The Acme Brick Company and the Malvern Brick and Tile Company, operate adjacent pits in a deposit located just beyond the southeast edge of the city of Malvern. Both companies use the clay locally in the manufacture of face-brick, tile and fire brick, Missouri flint clay or Arkansas kaolin frequently being added to insure high heat duty refractories.

Unfortunately, few records of boring or test pitting by the State Mineral Survey are available. The amount of effort available to the writer permitted only cursory examination of more obvious exposures and a more detailed examination of the deposit being mined at Malvern. Six outcropping deposits were sampled and a description of their occurrence and fired characteristics follows. All of these deposits merit further examination by anyone interested in mining clay in this county.

In addition to the Malvern deposit, three of the clays tested were in the upper range of the intermediate heat duty plastic fire clays and could, therefore, possibly be sweetened with more refractory materials to make high heat duty refractories. By selective mining deposits such as these, it would also seem highly probable that ball, wad, and sagger clays could be produced for other ceramic industries.

Samples HS-1 and HS-6

Location: NE¼ NW¼ NE¼ Sec. 25, T. 4 S., R. 17W.

These two samples were taken from different horizons in the west working face of the clay pit operated by the Malvern Brick and Tile Company. HS-1 was taken from a 2-foot interval of carbonaceous clay overlying a bed of light gray clay which was as much as 15 feet thick. HS-6 represented a 5½-foot channel sample of this light gray clay bed.

Bed HS-1 varies from 1 foot to 4 feet thick along a crescent-shaped exposure in the side of the pit; both ends of the lens rising to the stripped surface at the top of the pit. Several discontinuous lignite bands, each less than an inch thick, occur in this black, fat, carbonaceous clay. The exposure suggests that the bed was deposited is a shallow depression which had been cut in the underlying gray clay bed.

Bed HS-6 is characteristically a light gray blockey clay with no apparent bedding but in which frequent partings show leaf impressions and occasional lignitized plant materials. It is underlain and in most places covered by carbonaceous clays and beds of soft brown lignite. This horizon changes abruptly to light colored fine sand to the west and mining has exposed pillars of similar sand in the pit. These pillars are many feet across and usually occupy the entire gray clay interval (HS-6), the horizontal change from clay to sand being abrupt along a nearly vertical contact.

At the present time it is necessary to remove from 8 to 20 feet of overburden from this deposit in order to strip the clay. The upper part of this material consists for the most part of fine mustard-colored sand with considerable gravel mixed with the sand near the top. An excellent exposure at the west end of the pit showed the mustard-colored sand to be underlain by 2 feet of medium-sized round to flattened gravels in a matrix of dark slate gray clay. This gray clay had many red iron stain streaks and was in turn underlain by 6 inches of laminated gray clay and sand which capped bed HS-6 at this point.

The clay deposit in which the two pits are operating consists of a lenticular body of buff burning clay, as much as 40 feet thick and covering an area over 200 acres. A few miles to the northeast, near the town of Gifford, there is another large clay body which has been outlined by drilling. The exact size of the deposit was not available to the Division of Geology but firing tests on samples of this clay were obtained and showed characteristics essentially the same as HS-6.

Sample No. HS-1

Tested by Plummer

Plastic and Dry Properties

% Water of plasticity	32.39
% Shrinkage water	14.72
% Pore water	17.67
% Volume shrinkage	24.32
% Linear shrinkage (measured)	4.33
% Linear shrinkage (calculated)	7.52

Fired Properties

P.C.E.	cone 31-32					
Best firing range	cone 6 to cone 10					
Fired to cone	05	04	01	4	8	13
Fired color	nearly white	nearly white	nearly white	ivory white	light cream	gray & cream
Firing behavior	O.K. to cone 01; slight warp and cracking					
% Volume shrinkage	7.80	12.97	22.29	25.01	27.65	33.57
% Total volume shrinkage	32.12	37.29	46.61	49.33	51.97	57.89
% Linear shrinkage (measured)	2.02	2.26	4.31	6.24	6.99	8.12
% Linear shrinkage (calculated)	2.67	4.54	8.07	9.14	10.25	12.76
% Total linear shrinkage (measured)	6.35	6.59	8.64	10.57	11.32	12.45
% Absorption 24 hours cold water	22.62	19.90	11.87	9.59	6.97	1.37
% Absorption 5 hours boiling water	23.68	20.95	13.19	11.28	8.40	2.29
Saturation Coefficient	0.96	0.95	0.90	0.85	0.83	0.60
% Apparent porosity	37.89	35.41	24.93	22.11	17.05	5.04
Apparent specific gravity	2.58	2.62	2.52	2.52	2.45	2.32
Bulk specific gravity	1.60	1.69	1.89	1.96	2.03	2.20
Hardness, as to steel	softer	softer	as hard	harder	harder	harder

Before the addition of tempering water this clay was a light brown in color, indicating the presence of some lignite, or lignitic materials. After pugging with water the clay is quite plastic, and works well in hand molding, being smooth, slick and somewhat rubbery. The test bricks dried without cracking, or warping or cupping, as should be expected with the relatively low drying shrinkage.

Sample No. HS-1 is the purest of the Wilcox clays tested for this report, judging both from fired colors and chemical analyses of a portion of the clays tested. This is a high heat duty plastic fire clay of the ball clay type, and compares well with many of the ball clays being sold to the whiteware and other ceramic industries. In the lower temperature range the fired color is white to nearly white. At cone 8 the color is a light cream or ivory. Shrinkages are moderate for this type of clay, and the bonding qualities are apparently good. The relatively high alumina (27.67%) and the low silica (57.2%) indicates a fairly high percentage of kaolinite. This is confirmed by the pyrometric cone equivalent of cone 31-32.

Brick and tile or other structural products made from this clay are of exceptional quality both because of the fired colors and the dimensional stability within the firing range. It is necessary to mix some sand or grog with the clay because of its "tightness" due to fine grain size. Some cupping was observed to occur in drying as revealed by the difference between measured and calculated shrinkages, but this defect would be less likely to occur with stiff mud extrusion, and not at all with dry pressing.

Due to its exceptional refractoriness this clay is especially valuable as a raw material for the manufacture of fire brick and other refractory shapes. The P.C.E. of cone 31-32 is at the minimum for high heat duty refractories, and for this reason it has proved advisable to add a small proportion of a more refractory clay, or a refractory grog such as alumina fines.

Sample No. HS-6

Tested by Plummer

Plastic and Dry Properties

% Water of plasticity	24.41
% Shrinkage water	8.79
% Pore water	15.62
% Volume shrinkage	16.03
% Linear shrinkage (measured)	4.48
% Linear shrinkage (calculated)	5.07

Fired Properties

P.C.E.	cone 31					
Best firing range	cone 5 to cone 9					
Fired to cone	05	04	01	4	8	13
Fired color	nearly white	ivory	ivory	cream	cream	light gray
Firing behavior	satisfactory throughout test range					
% Volume shrinkage	4.50	5.74	11.52	15.69	22.24	25.30
% Total volume shrinkage	20.53	21.77	27.55	31.72	38.27	41.33
% Linear shrinkage (measured)	0.75	1.08	3.48	4.32	5.91	6.11
% Linear shrinkage (calculated)	1.52	1.94	3.99	5.53	8.03	9.27
% Total linear shrinkage	5.23	5.56	7.96	8.80	9.39	10.59
% Absorption 24 hours cold water	17.75	16.68	11.48	8.91	4.35	0.36
% Absorption 5 hours boiling water	18.30	17.37	12.62	10.01	5.06	0.61
Saturation Coefficient	0.97	0.96	0.91	0.89	0.86	0.59
% Apparent porosity	32.21	31.09	23.98	19.92	10.93	1.37
Apparent specific gravity	2.60	2.60	2.50	2.49	2.42	2.27
Bulk specific gravity	1.76	1.79	1.90	1.99	2.16	2.24
Hardness, as to steel	softer	softer	softer	harder	harder	harder

The clay sample, as received, was a light buff gray. After forming into test bricks and drying the color was a warm light gray. The clay is plastic, has excellent working properties, and the small test bricks dried without warping or cracking.

Clay sample No. HS-6 is very similar to other Hot Spring county samples Nos. 1, 3, 7 and 8. They are all intermediate or high heat duty plastic fire clays with the general characteristics of ball clays. The pyrometric cone equivalent of HS-6 was determined in this test as cone 31. As previously stated, further tests might place the P. C. E. one cone higher or lower. In the case of this clay a half cone's difference would place it in the high heat duty class. In comparison runs with other laboratories we have found that our determinations tend to be about one cone low. In any case, clay No. HS-6 is well suited to the manufacture of fairly high grade refractories.

Despite the fact that the iron oxide content of this clay is slightly higher than that for HS-1 the fired colors are about the same, ranging from nearly white through light cream to gray. The comparatively low content of titanium oxide probably accounts for the clear colors in the higher temperature range. Although these colors are slightly darker than the average of commercial ball clays this clay should be acceptable to the pottery manufactures as a ball clay suitable for any but the most exacting requirements.

Clay No. HS-6 is also well suited to the manufacture of high grade structural products such as brick and tile. The drying shrinkage is low for a clay of this type, and the firing shrinkages are moderate. The firing range is adequately long, and the clay is capable of nearly complete vitrification if firing to higher temperatures should be required.

Sample No. HS-3

Location: SW¼ SW¼ SW¼ Sec. 2, T. 5 S., R. 17 W.

On the east side of the road a whitish-gray plastic clay with frequent red spots and streaks outcrops beneath 3 feet of sandy soil. Auger holes show this clay to be at least 6 feet thick along the road. With depth the clay becomes darker gray and dry but is plastic when wet. The extent of the deposit was not determined, but it could amount to 40 acres or more. The laboratory report below shows the material to be a light firing clay with excellent raw and fired characteristics. Its location adjacent to a railroad and within 3 miles of Malvern would favor further examination to determine the extent of the deposit.

The original color of this clay is gray and tan, but after being pugged and dried the color is a light gray. The tempered clay is quite plastic and smooth with very good working properties. No warping or cracking was observed on drying the test bricks. A rather large discrepancy between the measured and calculated shrinkages indicates that shrinkage was not equal for all dimensions. The test bricks show slight cupping, but also the surface that was on top in the mold, where shrinkage measurements were made, shows less shrinkage than the rest of the brick. Test data follows:

Sample No. HS-3

Tested by Plummer

Plastic and Dry Properties

% Water of plasticity	27.61
% Shrinkage water	10.60
% Pore water	17.01
% Volume shrinkage	18.46
% Linear shrinkage (measured)	3.55
% Linear shrinkage (calculated)	5.82

Fired Properties

P.C.E.	cone 31					
Best firing range	cone 4 to cone 8					
Fired to cone	05	04	01	4	8	13
Fired color	nearly white	nearly white	ivory	cream	cream	light gray
Firing behavior	satisfactory throughout test range					
% Volume shrinkage	5.60	9.34	17.44	21.17	26.57	30.19
% Total volume shrinkage	24.06	27.80	35.90	39.63	45.03	48.65
% Linear shrinkage (measured)	1.62	1.70	5.09	5.72	7.21	8.26
% Linear shrinkage (calculated)	1.90	3.20	6.17	7.64	9.80	11.29
% Total linear shrinkage	5.15	5.25	8.64	9.27	10.86	11.50
% Absorption 24 hours cold water	19.13	16.79	10.24	7.81	2.91	0.52
% Absorption 5 hours boiling water	20.35	18.25	11.64	9.19	3.59	0.69
Saturation Coefficient	0.94	0.92	0.88	0.85	0.81	0.75
% Apparent porosity	35.00	32.67	22.81	18.84	7.90	1.59
Apparent specific gravity	2.65	2.66	2.54	2.53	2.39	2.35
Bulk specific gravity	1.72	1.79	1.96	2.05	2.20	2.31
Hardness, as to steel	softer	softer	softer	softer	harder	harder

Possibly clay No. HS-3 should be considered equal in quality to No. HS-1. The only respect in which No. HS-3 could be considered inferior is the slight pink mottling that shows on a white background in the test bricks fired from cone 05 to cone 01. This pink color could be due to slight contamination or to portions of the bed that could be eliminated for ball clay uses.

The pyrometric cone equivalent of cone 31 places this clay near the upper limit of the intermediate heat duty plastic fire clays. Determinations of P.C.E.'s should not be considered exact where only one sample has been tested and only one fusion run. It is possible and even probable that the pyrometric cone equivalent is the same as that for sample No. HS-1, cone 31-32.

This sample should be classed as an acceptable grade of white to ivory-firing ball clay, that with the possible exception of fired color, has excellent ceramic properties which recommend its use in the pottery industries. It should also be suitable for use as an all-clay body either for earthenware or stoneware. Near vitrification the clay has a high density and a pleasing light gray color.

A high grade of brick and tile or other structural clay products could be made from this clay. Although the drying and lamination problems would be simplified by the addition of some grog or sand it does not seem to be entirely necessary for manufacturing processes requiring stiff mud extrusion.

Like clay No. HS-1 this material is well suited to the manufacture of refractories such as saggers and fire bricks. The pyrometric cone equivalent could easily be brought into the high heat duty class by minor additions of more refractory materials.

Sample No. HS-5

Location: NE¼ Sec. 5, T. 6 S., R. 17 W.

Tested by Plummer

Plastic and Dry Properties

% Water of plasticity	25.56
% Shrinkage water	15.14
% Pore water	10.42
% Volume shrinkage	29.23
% Linear shrinkage (measured)	7.69
% Linear shrinkage (calculated)	8.92

Fired Properties

P.C.E.	cone 23					
Best firing range	cone 01 to cone 14					
Fired to cone	05	04	01	4	8	13
Fired color	cream	cream	buff	buff	light buff	buff
Firing behavior	satisfactory throughout test range					
% Volume shrinkage	1.55	2.50	3.73	4.96	5.19	6.98
% Total volume shrinkage	30.78	31.73	32.96	33.92	32.50	36.21
% Linear shrinkage (measured)	0.39	0.94	2.08	2.49	2.50	2.86
% Linear shrinkage (calculated)	0.54	0.84	1.25	1.70	2.29	2.39
% Total linear shrinkage	8.08	8.63	9.77	10.18	10.19	10.55
% Absorption 24 hours cold water	12.89	11.76	9.75	8.59	7.80	6.48
% Absorption 5 hours boiling water	14.99	14.00	12.83	11.77	11.37	10.70
Saturation Coefficient	0.86	0.84	0.76	0.73	0.69	0.61
% Apparent porosity	28.03	26.32	24.38	22.72	21.94	21.08
Apparent specific gravity	2.60	2.55	2.51	2.50	2.47	2.50
Bulk specific gravity	1.87	1.88	1.90	1.93	1.93	1.97
Hardness, as to steel	softer	softer	softer	as hard	harder	harder

Sample HS-5

This sample was obtained by two 4-foot auger holes and represents 8 feet of a total of approximately 20 feet of lead-gray clay carrying some coarse grit. The clay where observed was overlain by from 0 to 3 feet of sandy soil with some gravel. The whole area was covered by pine forest. The extent of the deposit was not determined.

In the dry sample, before grinding, this clay was gray with a brownish tint. The dried test bricks did not show the brown tint to any extent. The clay is plastic and has good working properties, although somewhat sticky. One out of the six test bricks warped slightly, but no other drying defects were noted.

This is a low heat duty fire clay that is apparently somewhat siliceous to judge from the firing characteristics and from a loss on ignition of only 5%. Nevertheless, the plastic and dry properties are those of a plastic clay with a high clay mineral content, perhaps due to the fine size of particles in the non-clay fraction.

The pyrometric cone equivalent of only cone 23 limits this clay for use in refractories to saggers, kiln furniture and other relatively low temperature uses.

The clay is well suited for use in the manufacture of structural clay products such as brick and tile. The drying shrinkage is moderately high, but apparently the clay is open enough to prevent serious drying trouble. Saturation coefficients are relatively low, indicating that a weather resistant product could be manufactured at firing temperatures around cone 01, although a temperature as high as cone 4 might be advisable. The fired colors vary from cream to various shades of clear buff. Firing shrinkages are low, and the firing range is surprisingly long. Both of these properties are decided advantages in the manufacture of products such as brick and tile.

Due to the fact that absorptions and porosity remain fairly high even at cone 13 it is not likely that this clay would suit the pottery manufacture unless it should be combined in a body, or with a tighter lower temperature clay.

Sample No. HS-7

Location: Center Sec. 7, T. 5 S., R. 16 W.

On the northeast side of State Highway 9 approximately 4 miles south of Malvern, the roadcut reveals up to 9 feet of clay and sandy clay capped by about 1 foot of gravel. At the point sampled, the gravel was underlain by 4 feet of gray, very sandy clay with considerable reddish-brown iron stain. This was in turn underlain by 4 feet of gray plastic clay with some yellow stain along joints. The lower 4 feet was sampled and the laboratory report below shows the clay to be a buff firing clay of good quality. Preliminary examination revealed that the deposit could be of considerable size, but conclusive information can only be obtained by further digging.

This is a light gray buff clay in the dry green state. After tempering with water the clay is plastic and works well in hand molding. One out of six test bricks warped slightly, but on the whole the drying characteristics are good.

According to the pyrometric cone equivalent determination, and other ceramic data, this is an intermediate heat duty plastic fire clay. Its characteristics are those of a ball clay, but due to the fired colors and a silica content slightly above normal for a ball clay the pottery trade would probably consider this a sagger clay. It would be entirely suitable for use in the manufacture of pottery, however, where the fired color would not be objectionable. It is probable that the vitrification temperature would be too high for its economical use in making stoneware.

Within its heat range it should make an excellent refractory, either in saggers or other shapes such as fire bricks because of its volume stability over a wide range of temperatures.

The clay is equally well suited to the manufacture of brick and tile, or other structural clay products. The drying shrinkage is slightly high, but not excessive. Firing shrinkages, however, are comparatively low, and within the useful firing range change of size with increasing temperature is conveniently slight. For some applications in the structural clay products industry the firing temperature could be below the cone 5 given as a minimum in the table; perhaps in some cases as low as cone 02.

Sample No. HS-7
Tested by Plummer

Plastic and Dry Properties

% Water of plasticity	26.59
% Shrinkage water	13.75
% Pore water	12.84
% Volume shrinkage	25.56
% Linear shrinkage (measured)	5.66
% Linear shrinkage (calculated)	7.89

Fired Properties

P.C.E.	cone 29					
Best firing range	cone 5 to cone 13					
Fired to cone	05	04	01	4	8	13
Fired color	pink & white	nearly white	mottled cream	cream	dark cream	light buff
Firing behavior	satisfactory throughout test range					
% Volume shrinkage	4.46	6.02	9.79	12.49	13.33	18.47
% Total volume shrinkage	30.02	31.58	35.35	38.05	38.89	44.03
% Linear shrinkage (measured)	1.13	1.18	2.89	3.95	4.05	5.63
% Linear shrinkage (calculated)	1.52	2.04	3.38	4.35	4.65	6.59
% Total linear shrinkage (measured)	6.79	6.84	8.55	9.61	9.71	11.29
% Absorption 24 hours cold water	15.84	14.36	10.83	8.99	6.86	3.66
% Absorption 5 hours boiling water	16.76	15.28	12.17	10.45	8.26	4.58
Saturation Coefficient	0.95	0.94	0.89	0.86	0.83	0.80
% Apparent porosity	30.50	28.42	23.49	20.80	16.60	9.76
Apparent specific gravity	2.62	2.60	2.52	2.51	2.41	2.36
Bulk specific gravity	1.82	1.86	1.93	1.99	2.01	2.13
Hardness, as to steel	softer	softer	softer	harder	harder	harder

Sample No. HS-8

Location: SE¼ Sec. 9, T. 6 S., R. 16 W.

On the north side of the road just west of the railroad in the small town of Rolla, there is a 12-foot bank of gray clay and intercalated layers of mustard-colored fine sand. This same sequence is observable for several hundred feet northward along the railroad cut. A representative sample was obtained from auger holes stepped down the 12-foot bank, and the report below gives the results from laboratory tests on this material.

The sample as received was a mixture of gray and yellow clay, but was gray buff in appearance after grinding. The tempered clay is smoothly plastic and its working properties are excellent so far as hand molding is concerned.

Clay No. HS-8 is an intermediate heat duty plastic fire clay, which probably would be considered a sagger clay by those supplying clays to potteries. Both its firing characteristics during the process of manufacturing and in service are judged to be favorable to its use in making fire bricks and other refractories. The P.C.E. of cone 30-31 is surprisingly high in view of the rather high iron content.

This clay is also well suited to the manufacture of brick and tile and similar products. Within the recommended firing range the fired color is a pleasing buff, although somewhat darker than many similar clays from the Wilcox group. There is some demand for pink face bricks. If weather conditions in service were not to be too severe this clay could be fired to cone 05 or 04 to produce a very pleasing pink brick.

The drying shrinkage is moderate, and firing shrinkages progress slowly over the firing range, insuring close sizing on the fired brick. The recommended firing temperature of cone 9 or higher is in the upper part of the usually employed commercial firing temperatures, but it is probable that lower temperatures could be used for some grades of brick or tile not intended for severe weather resistance.

Owing to the rather dark fired color and some iron specks it is probable that this clay should not be recommended for use in the pottery industry.

Sample No. HS-8
Tested by Plummer

Plastic and Dry Properties

% Water of plasticity	26.24
% Shrinkage water	10.77
% Pore water	15.47
% Volume shrinkage	19.47
% Linear shrinkage (measured)	6.06
% Linear shrinkage (calculated)	6.12

Fired Properties

P.C.E.	cone 30-31					
Best firing range	cone 9 to above cone 13					
Fired to cone	05	04	01	4	8	13
Fired color	mottled pink	mottled pink	pink & white	mottl'd buff	mottl'd buff	mottled buff
Firing behavior	satisfactory throughout test range					
% Volume shrinkage	5.58	7.49	9.78	14.60	15.12	18.63
% Total volume shrinkage	25.08	26.96	29.25	34.07	34.59	38.10
% Linear shrinkage (measured)	1.52	1.47	2.88	4.39	4.39	5.51
% Linear shrinkage (calculated)	1.90	2.57	3.38	5.13	5.31	6.63
% Total linear shrinkage	7.58	7.53	8.94	10.45	10.35	11.57
% Absorption 24 hours cold water	18.58	16.47	13.84	11.10	9.74	6.51
% Absorption 5 hours boiling water	19.77	17.52	15.04	12.61	11.46	8.92
Saturation Coefficient	0.94	0.94	0.92	0.88	0.85	0.73
% Apparent porosity	34.80	31.71	27.97	24.72	22.58	18.38
Apparent specific gravity	2.70	2.65	2.58	2.60	2.54	2.52
Bulk specific gravity	1.76	1.81	1.86	1.96	1.97	2.06
Hardness, as to steel	softer	softer	softer	harder	harder	harder

Sample No. HS-15

Location: NE¼ Sec. 35, T. 6 S., R. 18 W.

This area was previously reported by Branner as having 4 feet of gray clay exposed in a creek bank about a quarter of a mile above Sulphur Springs, now called Brown Springs. The clay was collected by a 2-foot auger hole in the creek bottom and from the 2 feet exposed in the bank. The maximum overburden consisted of from 2 to 3 feet of gravel. Four feet does not represent the total thickness of clay but rather all that could be sampled with the equipment available. Mr. Gray, the property owner, reported that 10 feet of light colored clay was penetrated in a well dug 200 yards south of the point sampled, but the gravel overburden prevented digging a test at this point. The laboratory report below shows the clay sampled to have an excellent light color on firing and its other characteristics are such as to make it worthy of further examination.

As received in the laboratory this clay was a light gray-brown in color. This color is doubtless due in part to the presence of lignite or lignitic compounds. The clay is plastic, and although a little sticky the workability in the plastic state is good.

Clay No. HS-15 is a low heat duty fire clay. Although it is a siliceous clay as shown both by the chemical composition and its open firing characteristics at elevated temperatures, it is also a fairly plastic clay, probably due to the fine particle size of both the clay and the quartz constituents. The drying shrinkage is moderately high, but the firing shrinkages are low.

Within its useful temperature range this clay would make refractory shapes having some desirable characteristics not present in higher grade, or less siliceous clays, chiefly due to slight changes in both dimensions and color over a wide temperature range. Finished refractory shapes fired to a fairly high temperature could be expected to be free from shrinkage in use, with a possibility of slight expansion. Such clays are reputed to be very well suited to the manufacture of ladle brick for the steel industry.

Although the burning temperature would have to be relatively high this clay would work very satisfactorily in the manufacture of brick and tile and other structural clay products due to its open firing and the slow decrease in size with increasing temperatures. The fired colors are excellent even as high as cone 13.

If used in a ceramic body containing feldspar, nepheline syenite or other fluxes, but no potters flint, this clay would have some possibilities for use in the pottery industry where a cream or ivory body was not objectionable.

Sample No. HS-15

Tested by Plummer

Plastic and Dry Properties

% Water of plasticity	22.85
% Shrinkage water	12.10
% Pore water	10.75
% Volume shrinkage	23.50
% Linear shrinkage (measured)	6.06
% Linear shrinkage (calculated)	7.28

Fired Properties

P.C.E.	cone 23					
Best firing range	cone 9 to above cone 13					
Fired to cone	05	04	01	4	8	13
Fired color	pink & white	ivory	ivory	light cream	cream	buff
Firing behavior	satisfactory throughout test range					
% Volume shrinkage	2.32	2.50	2.64	3.96	4.15	6.70
% Total volume shrinkage	25.82	26.00	26.14	27.46	27.65	30.20
% Linear shrinkage (measured)	0.53	0.85	1.23	1.80	2.26	2.41
% Linear shrinkage (calculated)	0.77	0.84	0.87	1.35	1.42	2.29
% Total linear shrinkage	6.59	6.91	7.29	7.86	8.32	8.47
% Absorption 24 hours cold water	12.84	12.46	10.76	9.82	9.04	6.78
% Absorption 5 hours boiling water	13.38	13.12	11.96	11.03	10.62	9.09
Saturation Coefficient	0.96	0.95	0.90	0.89	0.85	0.75
% Apparent porosity	25.15	24.53	22.48	21.05	20.28	17.82
Apparent specific gravity	2.51	2.48	2.43	2.42	2.40	2.38
Bulk specific gravity	1.88	1.88	1.88	1.91	1.91	1.96
Hardness, as to steel	softer	softer	softer	softer	softer	harder

CHAPTER VI

CLAY LOCALITIES OF PULASKI AND SALINE COUNTIES

General

Extensive deposits of high-alumina clay have been revealed by drilling in these two counties. Unique in their physical character and origin, they are here treated as a unit rather than discussed separately by county. This section is not based on data collected by the Division of Geology, but rather is an abstract of previous work.

Location and Description of High Alumina Clay Deposits

These clays are found in a band roughly 7 miles wide extending southwestward from Little Rock for a distance of about 25 miles. An estimate by Tracey (1944), based on U. S. Bureau of Mines drilling data, stated that there probably were deposits totaling 100 million tons of clay lying beneath overburden that does not exceed 50 feet. This clay normally contains more than 35 per cent of alumina. Tracey further states that "minable deposits range from those that have an areal extent of less than one acre and contain less than 50,000 tons to those that cover a hundred acres or more and contain over 15 million tons of high alumina clay."

Geologic History

These deposits differ radically from the other Wilcox clays essentially in that they are locally derived and in some cases might even be considered residual. Tracey, who has an excellent grasp of the history of the bauxite region based on factual data, described it as follows:

> The clays of the bauxite-kaolin zone were formed on an ancient land surface. In order to understand their nature, distribution, and extent, it is necessary to know something of the geologic history of the district, and particularly of the physiography during the period in which the clays were formed.
>
> Prior to the formation of the clays, probably in Cretaceous time, the Paleozoic strata of the region were invaded by igneous rocks of the type known as nepheline syenite. The principal constituents of this rock are nepheline and the potassium feldspar, microcline, both of them silicates high in alumina and both, especially the nepheline, easily decomposed by weathering. The moderately metamorphosed Paleozoic rocks were eroded more deeply than the more resistant syenite, which stood forth in a series of rather low hills. During Midway time, a sea advanced over this land surface, and the syenite hills then stood above the sea as islands. Marls and fossiliferous limestones and, later, black silty clays were deposited on the sea floor, lapping on to the flanks of the syenite hills.
>
> Retreat of the Midway sea was followed by a profound weathering of the rocks exposed, which resulted in kaolinization, particularly of the syenite, and in the development of bauxite by removal of silica. The kaolinitic clay and the bauxite developed by the weathering do not form a mantle of even thickness, but lie mainly upon the sides of the valleys draining the syenite hills and upon the surface of the gently dipping Midway clay at the base of the hills. Some of the deposits, therefore, extend along old valleys in the syenite, nearly filling the smaller ones, and others lie at the base of the hills.
>
> Soon after the formation of the high-alumina clays and the bauxite, the region became swampy, and the lignite beds and carbonaceous silty clays of Wilcox age were deposited. Upon these, streams deposited brown sands and clays that buried most of the syenite hills. The thickness of the Wilcox sediments increases away from the higher parts of the buried hills, and these sediments are more than 400 feet thick where they overlie some of the clay deposits.
>
> The uppermost sediments in the area are clays, sands, and gravels of alluvial origin, which in places reach a thickness of more than 100 feet. The Wilcox and younger sediments become thin or disappear where the syenite is close to the present land surface. The shallower deposits of clay and bauxite are thus found in the neighborhood of syenite outcrops, particularly in those areas where the Midway clay lies close to the surface.

Rauch Deposit

The U. S. Bureau of Mines consolidated the available data on two large clay deposits in the area and included this information in their series of Reports of Investigations, entitled "Investigation of Arkansas Bauxite." Volumes V and VI of this series (R. I. 4255 and R. I. 4256) give the logs of drill holes and chemical analysis of the cores from the Rauch clay deposit. The following discussion is based on this core information.

The Rauch area clay deposit underlies parts of the SE¼ of Sec. 4, the SW¼ of Sec. 3, the E½ of Sec. 9, and the W½ of Sec. 10, T. 1 S., R. 12 W., Pulaski County, Arkansas, approximately 5 miles south of Little Rock.

All of the clay in the Rauch area deposit, Pulaski County, Arkansas, occurs in the bauxite-kaolin zone comprising the post-Midway pre-Wilcox land surface and is associated genetically and physically with bauxite deposits in the vicinity. It occurs largely in a basin between syenite masses and extends eastward beyond the area drilled but at greater depth.

The deposit has been outlined by the drilling of 75 holes. Thirty-four of these holes were drilled in the Rauch deposit and 41 in the Rauch Extension which lies to the northeast. Clay underlies at least 250 acres and ranges in thickness from 10 to 65 feet. Drilling indicates the probability of a continuous deposit of high-alumina clay containing over 15 million tons covered by an average of about 40 feet of overburden. The analysis of the cores shows that this clay contains an average of about 36 per cent alumina, 40 per cent silica, and 8 per cent iron and titanium oxides. Iron occurs in the clay principally as small, hard pellets of siderite and the titanium as ilmenite.

Pine Haven Deposit

This deposit underlies about 200 acres and centers at the intersection of sections 4, 5, 8 and 9, T. 2 S., R. 14 W., approximately 1 mile northwest of the town of Bauxite in Saline County. It occurs as a blanket varying in thickness from 5 feet to over 45 feet but averaging about 30 feet. The overburden ranges in thickness from 17 feet to 66 feet, with an average of about 30 feet. From the data collected by the U. S. Bureau of Mines (R. I. 4266) the deposit is indicated to contain over 6 million tons of high-alumina clay with an average content of 38% alumina, 35% silica. As an impurity the clay contains iron, the average content reported as the oxide is about 7%. Here as in the Rauch deposit the iron is in the form of hard siderite pellets and layers. Titanium oxide in the form of ilmenite makes up probably 2% to 3% of the total.

Firing Characteristics

The Bureau of Mines was primarily interested in alumina sources and so no data were reported on the possible ceramic applications of these materials. Crockett (1945) who was at that time an engineer with the Niloak Company of Little Rock, investigated some of the high-alumina clays and reported the following:

Sample No.	LR-A4	LR-A5	LR-A6	LR-A7
Raw Color	light gray	light gray	light creme	dark gray
100M Wet Res.	3.8%	15.5%	32.0%	6.1%
200M Wet Res.	8.1	10.4	12.4	7.3
300M Wet Res.	3.8	4.6	7.7	3.2
% H_2O Plasticity	38.4	38.0	35.6	39.1
% Lin. Dry Shrink.	5.2	5.0	4.0	7.6
Raw Modulus Rupt.	177psi	162psi	118psi	225psi
Cone 8 (2237°F)				
Tot. Lin. Shr.	19.2%	21.2%	11.0%	16.3% (bloated)
Lin. Firing Shr.	14.0	16.2	7.2	8.0
% Absorption	17.8	16.1	20.1	0.0
Color	Lt. Creme (specked)	Lt. Creme (specked)	Lt. Creme (specked)	Gray-specked
Cone 11 (2345°F)				
Tot. Lin. Shr.	20.4%	23.0%	12.6%	16.0% (bloated)
Lin. Firing Shr.	15.1	18.0	8.6	7.6
% Absorption	16.2	15.3	18.3	0.0
Color	Lt. Creme (specked)	Lt. Creme (specked)	Lt. Creme (specked)	Gray-specked
P.C.E.	35(3245°F)	35(3245°F)	32(3092°F)	20-23(2768-76°F)
Chemical Analysis*				
Al_2O_3	42.3%	42.9%	35.0%	25.7%
SiO_2	35.5	33.8	40.6	58.8
Fe_2O_3	1.5	1.2	5.9	3.5
TiO_2	2.8	2.8	2.8	1.2
Ignition	16.9	18.3	14.9	9.0
FeO	0.2	0.2	3.5	0.4
Insoluble	1.0	1.0	0.8	1.8
Remarks	bauxitic	bauxitic	coarse-grained	carbonaceous

* Chemical analysis by the field laboratory of the Ark. Bauxite Project, U. S. Bureau of Mines.

The firing was carried out in a Remmey No. 2150 test kiln on a 7-hour schedule. Sample LR-A6 had all of the material coarser than 200 mesh removed before firing.

It is especially noteworthy that the three samples characteristic of the high alumina clays in having 35 per cent or more of alumina had pyrometric cone equivalents of 32 to 35. Two of these clays also show high fired shrinkage, which seems to be the chief difficulty in the application of these clays. A report of further investigations on their firing characteristics will be published soon.

Other Wilcox Clay Deposits

Although the greatest part of this section has been given over to a discussion of high-alumina clays, the area also contains clays of the type found in the counties to the south. These are for the most part higher stratigraphically than the high alumina clays.

Sample No. P-1

An outcrop which possibly represents one of these upper clays is located in the SW¼ SE¼ SW¼ of Sec. 5, T. 1 S., R. 12 W., Pulaski County. The point samples was on the east side of the road on the south abutment of a railroad overpass. Fifteen feet of yellow to red cross-bedded sandstone, sand, silt and silty clay capped the exposure with about one-third of the upper 12 feet being made up of well cemented concretionary masses and erratic layers of ironstone and sand from 1 inch to 4 inches thick. Under this was 5 feet of gray, siliceous clay changing in color to purple at the base (P-1). This in turn was underlain by 9 feet of fine-grained sandstone with iron-cemented concretionary masses and 7 feet of brownish silt, fine sand and clayey sand. The ceramic report of this material follows.

Sample No. P-1
Tested by Plummer

Plastic and Dry Properties

% Water of plasticity	29.59
% Shrinkage water	12.94
% Pore water	16.65
% Volume shrinkage	22.55
% Linear shrinkage (measured)	5.48
% Linear shrinkage (calculated)	7.02

Fired Properties

P.C.E.	cone 20-23				
Best firing range	about cone 3 to cone 6; indications of overfiring at cone 12				
Fired to cone	05	01	5	8	12
Fired color	cream, br. specks	cream, br. specks	cream	grayed cream	light gray
Firing behavior	satisfactory to about cone 10				
% Volume shrinkage	3.26	12.36	21.15	28.87	26.48
% Total volume shrinkage	25.81	34.91	43.70	51.42	49.03
% Linear shrinkage (measured)	0.90	4.20	6.75	8.79	8.03
% Linear shrinkage (calculated)	1.11	4.32	7.64	10.75	9.75
% Total linear shrinkage	6.38	9.68	12.23	14.27	13.51
% Absorption 24 hours cold water	18.91	13.83	7.41	0.78	0.55
% Absorption 5 hours boiling water	19.65	14.51	7.89	1.20	0.97
Saturation Coefficient	0.96	0.95	0.94	0.65	0.57
% Apparent porosity	33.21	27.13	16.41	2.76	2.15
Apparent specific gravity	2.53	2.57	2.49	2.37	2.27
Bulk specific gravity	1.69	1.87	2.08	2.30	2.22
Hardness, as to steel	softer	as hard	harder	harder	harder

The unfired color of this clay is a rather light gray. After preparation to molding consistency with the addition of water the clay is plastic and has good working properties. Hand molded test bricks have a tendency to warp on drying, but it is possible that no drying problems would be encountered with stiff mud extrusion, or other methods of forming.

Sample No. P-1 is a low heat duty plastic fire clay limited in its usefulness as a refractory to installations not exceeding 2400° F. In the pottery industry it probably would be considered a sagger clay, or possibly even a wad clay.

Owing to its plasticity, bond strength and relatively low firing temperatures this clay has some of the characteristics of a ball clay, and is adapted to use in the manufacture of pottery where the fired color would not be objectionable.

Clays of this type are suitable for use in the structural clay products industries. The "tightness" of the clay and its tendency to warp and cup on drying might necessitate the addition of grog or sand for forming by the stiff mud method. Dimensions are fairly stable within the firing range, but the grog or sand additions would insure more uniformity of size in the finished product. The relatively low firing temperatures are decidedly advantageous to the use of this clay for the manufacture of brick and tile, or other heavy clay products. In many cases clays having similar characteristics are burned to temperatures as low as cone 01, but for the production of grade SW face brick a higher temperature appears to be necessary.

Several samples of clay from Saline county were collected during the present investigation but because of their lack of economic promise no description of these deposits or the firing characteristics of their clay is included. Rather, the reports of firing characteristics of eight clay samples from five townships within the county are given below as typical of the better clays which may be found. These reports by the State Mineral Survey are on samples obtained from test pits but no information is available on the thickness of clay which each sample represents.

State Mineral Survey Sample

Location: NW¼ Sec. 5, T2S, R12W

Tested by: Grace

Plastic and Dry Properties	
% Water of plasticity	24.5
% Volume shrinkage	27.8
% Linear shrinkage (measured)	8.52

Fired Properties

Best firing range								
Fired to cone	03	01	2	4	6	8	10	12
Fired color	white	white	white	light buff	light buff	buff	buff	buff
% Volume shrinkage	1.0	2.4	2.4	4.8	4.4	6.5	5.8	6.3
% Linear shrinkage (measured)	0.33	0.81	0.81	1.63	1.49	2.22	1.97	2.15
% Absorption	12.6	10.9	11.4	10.4	11.8	7.8	7.0	7.3
% Apparent porosity	24.2	21.5	23.0	20.9	17.3	15.8	14.1	14.8
Apparent specific gravity	2.56	2.50	2.57	2.52	2.44	2.46	2.38	2.39
Bulk specific gravity	1.94	1.96	1.96	1.98	2.01	2.04	2.04	2.04

Steel hardness at cone 2

State Mineral Survey Sample

Location: NW¼ Sec. 28, T2S, R12W

Tested by: Grace

Plastic and Dry Properties	
% Water of plasticity	24.3
% Volume shrinkage	28.0
% Linear shrinkage (measured)	8.58

Fired Properties

Best firing range: cone 01 to 6

Fired to cone	03	01	2	4	6	8	10	12
Fired color	buff	buff	buff	buff	tan	tan	tan	tan
% Volume shrinkage	1.0	1.8	1.5	2.9	4.4	5.5	6.0	7.5
% Linear shrinkage (measured)	0.33	0.60	0.50	0.98	1.49	1.87	2.04	2.57
% Absorption	10.3	8.2	9.3	8.5	8.2	7.3	8.8	6.6
% Apparent porosity	20.0	17.0	21.0	17.1	16.8	15.6	17.9	13.7
Apparent specific gravity	2.46	2.35	2.46	2.46	2.46	2.49	2.42	2.40
Bulk specific gravity	1.96	1.98	2.00	2.01	2.04	2.06	2.06	2.07

Steel hardness at cone 4

State Mineral Survey Sample

Location: Sec. 27, T2S, R14W

Tested by: Grace

Plastic and Dry Properties	
% Water of plasticity	33.1
% Volume shrinkage	9.4
% Linear shrinkage (measured)	3.04

Fired Properties

Best firing range

Fired to cone	03	01	2	4	6	10	12
Fired color	white	white	white	white	white	white	white
% Volume shrinkage	12.0	14.6	12.1	14.5	14.9	32.8	36.9
% Linear shrinkage (measured)	4.17	8.13	4.20	5.09	5.24	12.41	14.23
% Absorption	42.7	42.0	42.3	40.6	41.3	26.9	24.1
% Apparent porosity	55.8	55.6	55.0	54.8	55.5	45.4	42.1
Apparent specific gravity	2.96	3.03	2.92	3.02	2.99	3.10	3.05
Bulk specific gravity	1.31	1.32	1.30	1.36	1.34	1.69	1.76

Steel hardness at cone 10

State Mineral Survey Sample

Location: NE¼ Sec. 12, T2S, R15W

Tested by: Grace

Plastic and Dry Properties

% Water of plasticity	25.7
% Volume shrinkage	18.3
% Linear shrinkage (measured)	5.76

Fired Properties

Best firing range							
Fired to cone	01	2	4	6	8	10	12
Fired color	white	white	white	white	light buff	light buff	light buff
% Volume shrinkage	0.6	3.9	6.2	4.7	9.7	10.9	12.1
% Linear shrinkage (measured)	0.2	1.3	2.1	1.6	3.3	3.8	4.21
% Absorption	18.9	17.7	15.9	11.0	12.9	12.1	11.2
% Apparent porosity	32.2	30.9	28.5	30.3	24.7	22.9	21.3
Apparent specific gravity	2.51	2.54	2.52	2.53	2.46	2.44	2.44
Bulk specific gravity	1.70	1.75	1.80	1.77	1.86	1.90	1.91

Steel hardness at cone 8

State Mineral Survey Sample

Location: NW¼ Sec. 14, T2S, R15W

Tested by: Grace

Plastic and Dry Properties

% Water of plasticity	32.2
% Volume shrinkage	26.2
% Linear shrinkage (measured)	8.07

Fired Properties

Best firing range	cone 01 to 6						
Fired to cone	03	01	2	4	6	8	10
Fired color	white	white	buff	buff	buff	gray	—
% Volume shrinkage	12.7	7.1	12.9	21.2	26.9	27.5	30.2
% Linear shrinkage (measured)	4.4	2.4	4.5	7.6	9.9	10.2	11.3
% Absorption	13.3	17.7	17.1	8.4	3.4	0.3	0.2
% Apparent porosity	25.5	30.9	25.9	17.8	16.0	2.2	0.4
Apparent specific gravity	2.51	2.54	2.54	2.52	2.14	2.23	2.34
Bulk specific gravity	1.87	1.75	1.88	2.08	2.24	2.21	2.35

Steel hardness at cone 2

State Mineral Survey Sample

Location: NW¼ Sec. 5, T3S, R14W

Tested by: Grace

Plastic and Dry Properties

% Water of plasticity	26.7
% Volume shrinkage	16.2
% Linear shrinkage (measured)	5.7

Fired Properties

Best firing range	cone 2 to 8						
Fired to cone	01	2	4	6	8	10	12
Fired color	white	white	white	white	light buff	light buff	light buff
% Volume shrinkage	2.5	2.5	8.1	9.3	15.3	16.3	16.6
% Linear shrinkage (measured)	0.84	0.84	2.1	3.2	5.4	5.8	5.8
% Absorption	22.4	21.4	18.3	17.6	13.5	12.7	12.5
% Apparent porosity	37.1	36.3	32.6	31.3	26.2	25.2	24.6
Apparent specific gravity	2.65	2.66	2.65	2.58	2.65	2.61	2.61
Bulk specific gravity	1.66	1.70	1.78	1.78	1.94	1.95	1.97

Steel hardness at cone 8

State Mineral Survey Sample

Location: NE¼ Sec. 6, T3S, R14W

Tested by: Grace

Plastic and Dry Properties

% Water of plasticity	24.0
% Volume shrinkage	19.7
% Linear shrinkage (measured)	6.18

Fired Properties

Best firing range	cone 4 to 8							
Fired to cone	03	01	2	4	6	8	10	12
Fired color	buff	buff	buff	buff	tan	tan	tan	tan
% Volume shrinkage	2.2	1.8	1.6	1.1	1.3	0.2	0.4	0.3
% Linear shrinkage (measured)	0.74	0.60	0.53	0.37	0.44	0.07	0.13	0.10
% Absorption	17.6	17.8	17.6	17.6	18.0	16.7	15.4	15.8
% Apparent porosity	31.8	32.0	31.9	31.9	32.5	30.5	28.1	29.0
Apparent specific gravity	2.66	2.61	2.67	2.66	2.67	2.58	2.56	2.57
Bulk specific gravity	1.80	1.79	1.81	1.81	1.80	1.84	1.83	1.83

Steel hardness above cone 12

State Mineral Survey Sample

Location: SW¼ Sec. 3, T3S, R15W

Tested by: Grace

Plastic and Dry Properties

% Water of plasticity	20.4
% Volume shrinkage	9.7
% Linear shrinkage (measured)	3.13

Fired Properties

Best firing range								
Fired to cone	03	01	2	4	6	8	10	12
Fired color	buff	buff	buff	tan	tan	tan	tan	tan
% Volume shrinkage	2.0	2.4	0.4	1.9	2.0	2.6	2.7	2.0
% Linear shrinkage (measured)	0.67	0.80	0.14	0.30	0.67	0.87	0.90	0.67
% Absorption	15.5	15.7	15.3	13.9	13.7	13.5	12.0	12.0
% Apparent porosity	28.0	28.5	27.8	25.8	25.3	24.4	22.4	22.2
Apparent specific gravity	2.51	2.54	2.52	2.49	2.48	2.44	2.36	2.38
Bulk specific gravity	1.80	1.82	1.82	1.85	1.85	1.84	1.86	1.84

Steel hardness at cone 4

CHAPTER VII

NOTES ON CLAY OCCURRENCES IN OUACHITA AND MILLER COUNTIES

General

Since both of these counties contribute to the total Wilcox clay production in Arkansas, data on characteristic clays are included. There are many known deposits in this region and it is contemplated that another report will be released, representing a more detailed study of these clays.

Ouachita County

One pit is being worked in the county at the present time by the Hope Brick Company (O-2). A second deposit from which several hundred square yards of overburden has been removed is reported to be under lease to a refractory company (O-1). Both of these deposits are near the town of Chidester and are only two of many outcropping deposits to be seen within a radius of 5 miles of the town.

Sample O-1

This deposit is located in the SE¼ Sec. 7, T. 12 S., R. 18 W. About 4 feet of buff colored sand has been stripped from part of the deposit. The sample collected represents about 8 feet of clay; the total thickness of the deposit was not determined.

Sample No. O-1
Tested by Plummer

Plastic and Dry Properties

% Water of plasticity	35.78
% Shrinkage water	23.88
% Pore water	11.90
% Volume shrinkage	43.95
% Linear shrinkage (measured)	10.42
% Linear shrinkage (calculated)	12.92

Fired Properties

P.C.E.	cone 28				
Best firing range	cone 2 to cone 7				
Fired to cone	05	01	5	8	12
Fired color	yellow cream	light yellow	ivory yellow	yellow gray	gray with yellow
Firing behavior	satisfactory throughout test range				
% Volume shrinkage	6.83	16.04	16.22	17.59	19.88
% Total volume shrinkage	50.78	59.99	60.16	61.54	63.83
% Linear shrinkage (measured)	2.28	5.02	5.36	5.94	7.03
% Linear shrinkage (calculated)	2.32	5.65	5.72	6.25	7.13
% Total linear shrinkage	12.70	15.44	15.78	16.36	17.45
% Absorption 24 hours cold water	14.03	9.44	7.71	4.64	2.55
% Absorption 5 hours boiling water	15.37	10.38	8.58	5.55	3.69
Saturation Coefficient	0.91	0.91	0.90	0.84	0.69
% Apparent porosity	28.13	20.86	17.42	11.49	7.82
Apparent specific gravity	2.55	2.54	2.46	2.34	2.30
Bulk specific gravity	1.83	2.01	2.03	2.07	2.12
Hardness, as to steel	softer	harder	harder	harder	harder

As received this clay sample was a slightly brownish, rather dark gray. After mixing with water and pugging the clay is quite plastic and has good working properties. There is a tendency to warping on drying, at least in the hand molded test bricks.

This is a low heat duty plastic fire clay having the physical characteristics of a ball clay. Its use as a ball clay would be limited, however, to ivory-firing ceramic bodies. Although classed as a low heat duty fire clay the pyrometric cone equivalent of cone 28 places it in the upper limits of this class, indicating a refractory with a fairly extensive range of usefulness. Above the average plasticity and other characteristics suggest that this clay has very good bonding properties. The usefulness of this clay could be extended therefore, as a bond clay for more refractory grog, or with clays that have little bonding strength.

High grade structural clay products such as brick and tile can be made with this clay, but the tightness of the clay and its high drying shrinkage indicates that grog or sand would have to be added for stiff mud extrusion. Such additions tend to lighten the fired colors, and also alter the firing shrinkages to a considerable extent. So far as firing shrinkages are concerned the clay has a long firing range without grog or sand additions.

Sample O-2

This sample was taken from the southeast working face of the Hope Brick Works pit located near the center of Sec. 15, T. 12 S., R. 19 W. The overburden consists of from 2 to 5 feet of reddish iron stained clay and sandy clay which is underlain by over 10 feet of hard silty white to light gray non-bedded clay. In most of the pit this is underlain by 4 feet of pink to lavender carbonaceous clay, 1 foot of dark brown carbonaceous fine sand, and 4 feet of light gray, medium-grained sand with cross-bedded brown carbonaceous clay streaks.

Tested by Plummer
Sample No. O-2

Plastic and Dry Properties

% Water of plasticity	19.79
% Shrinkage water	5.95
% Pore water	13.84
% Volume shrinkage	10.97
% Linear shrinkage (measured)	3.84
% Linear shrinkage (calculated)	3.54

Fired Properties

P.C.E.	cone 20				
Best firing range	cone 9 to cone 12				
Fired to cone	05	01	5	8	12
Fired color	nearly white	nearly white	creamy white	cream	gray white
Firing behavior	excellent throughout test range				
% Volume shrinkage	0.10	3.22	5.77	11.30	17.07
% Total volume shrinkage	11.07	14.19	16.74	22.27	28.04
% Linear shrinkage (measured)	0.15+	0.94	1.86	3.35	5.58
% Linear shrinkage (calculated)	0.03	1.08	1.97	3.92	6.06
% Total linear shrinkage	3.94	4.78	5.95	7.44	9.67
% Absorption 24 hours cold water	15.81	14.39	12.41	8.64	3.87
% Absorption 5 hours boiling water	16.68	15.34	13.63	9.82	4.70
Saturation Coefficient	0.95	0.94	0.91	0.88	0.82
% Apparent porosity	29.69	28.07	25.62	19.64	10.01
Apparent specific gravity	2.53	2.54	2.53	2.49	2.37
Bulk specific gravity	1.78	1.83	1.88	2.00	2.13
Hardness, as to steel	softer	softer	softer	harder	harder

Clay sample No. 0-2 was a very light gray in color before firing. The working properties of the clay are good, although it is only fairly plastic, and somewhat mealy. This seems to be a very siliceous clay, to judge from the texture and from the small percentage of drying shrinkage. One test brick showed slight warping on drying, but this was probably due to unequal forming pressure.

Sample No. 0-2 is a low heat duty siliceous fire clay. All the ceramic data points to a clay containing a fairly high proportion of finely divided quartz. Although this clay is not especially refractory it would have limited usefulness in this field in application not subjected to high temperatures and where low iron content and dimensional stability were important.

This clay is well suited for use in the manufacture of brick and tile and other structural clay products. It is an "open" clay with low drying shrinkage. Both the content of organic materials and iron oxide seem to be low. Both of these characteristics are favorable to easy oxidation in the kiln. Firing shrinkages are low and do not increase rapidly with increase of temperature. The minimum firing temperature for brick or tile is given as cone 9 with the A.S.T.M. requirements for SW face bricks in mind. Owing to the fact that saturation coefficients remain high even at cone 12 it is judged that the cold water absorption should be reduced to a minimum of 8% so that the saturation coefficient requirements can be waived. Commercial methods of production might produce different results, but in general firing or "burning" temperatures have to be above the average for buff firing brick.

The fired colors of this clay are especially good, and light in shade. A very hard fired, low-absorption material is produced at cone 12. Due to this fact the clay is of interest to the manufacturer of stoneware, despite the high temperature required for firing.

Sample No. M-1
Tested by Plummer

Plastic and Dry Properties

% Water of plasticity	22.94
% Shrinkage water	10.20
% Pore water	12.74
% Volume shrinkage	19.11
% Linear shrinkage (measured)	5.94
% Linear shrinkage (calculated)	6.00

Fired Properties

P.C.E.	cone 23				
Best firing range	cone 6 to cone 12				
Fired to cone	05	01	5	8	12
Fired color	mottled cream	mottled cream	buff	grayed buff	grayed ivory
Firing behavior	satisfactory throughout test range				
% Volume shrinkage	0.71	1.72	6.33	11.78	13.33
% Total volume shrinkage	19.82	20.83	25.14	30.89	32.44
% Linear shrinkage (measured)	0.23+	1.12	1.81	3.32	3.86
% Linear shrinkage (calculated)	0.23	0.57	2.15	4.10	4.65
% Total linear shrinkage	5.71	7.06	7.75	9.26	9.80
% Absorption 24 hours cold water	15.27	14.32	10.93	6.15	4.77
% Absorption 5 hours boiling water	16.14	15.88	12.71	7.41	6.62
Saturation Coefficient	0.95	0.90	0.86	0.83	0.72
% Apparent porosity	28.89	28.90	24.15	18.91	13.57
Apparent specific gravity	2.52	2.56	2.51	2.48	2.37
Bulk specific gravity	1.79	1.82	1.90	2.01	2.05
Hardness, as to steel	softer	softer	harder	harder	harder

Miller County

The Dickey Clay Pipe Company for many years has mined clay from deposits a few miles northeast of Texarkana. Sample M-1 represents 6 feet of gray to slate gray clay from their pit located in the W½ of Sec. 3, T. 15 S., R. 28 W. This clay was overlain by 8 feet of iron-stained, dark slate gray clay which was also being mined. Some light gray sandstone exposed in the west side of the pit seemed to underlie the clay sampled. Although the Arkansas Geologic Map (1930) shows this area to be on the edge of the Midway outcrop, the firing characteristics of the clay are like those of a Wilcox clay, and it is so considered here.

Before this clay was prepared for testing it was a light, warm gray. After pugging the clay with water it was fairly plastic, and worked moderately well in hand molding. The tempered clay is somewhat mealy, due perhaps to a rather high percentage of non-plastics such as finely divided quartz. The test bricks were easily dried without warping or cracking. Test data follow.

Clay No. M-1 is a low heat duty fire clay, plastic so far as working properties are concerned, but probably mineralogically siliceous. As a refractory this clay could be classed as a sagger clay suitable for use at rather moderate temperatures such as employed in kilns firing brick and pottery.

This clay is very well suited for use in the manufacture of brick and tile and other structural clay products. Drying shrinkage and drying characteristics are favorable. Firing shrinkages are low, and the firing range long. Decrease in size with increasing temperatures is rather slight. For example, the measured linear shrinkage increases only 0.79% between cone 01 and cone 5, and increases only 0.55% between cone 8 and cone 12. The minimum firing temperature for structural clay products is given as cone 6 on the assumption that the product will be required to withstand severe freezing and thawing. In Arkansas and other states where winter weather is not severe the firing temperature could be lower.

The chief objection to this clay for use in the manufacture of buff-colored pottery is the rather high temperatures required to produce a hard-fired body. The use of suitable fluxes such as feldspar or nepheline syenite would overcome this objection to some extent. Although this clay was not vitrified at cone 12, the fired test bricks were quite dense and hard, and the color is good, indicating that a good grade of stoneware could be made from the clay, but at rather high temperatures.

CHAPTER VIII

THE UTILIZATION OF WILCOX CLAY IN CENTRAL ARKANSAS

General

The ceramic industry in Arkansas is nearly as old as the state itself. In 1843 a pottery was established in northern Dallas county, using the light firing clays of Wilcox age. Several more potteries were operating in Dallas county and neighboring Grant, Hot Spring and Saline counties by 1870.

With the building of the railroads it was inevitable that the industry soon would become localized in towns along these routes. In one of these favored towns, Malvern, a brick industry was started between 1870 and 1880. The potteries at Benton, Hope, Camden and Texarkana continued to operate while the early centers in Dallas county and elsewhere found themselves at a disadvantage for transportation and disappeared near the start of the century.

Many Arkansas potteries have stopped using local clays in favor of more uniform products obtained from out-of-state processors. However, the heavy ceramic industry has continued to use Wilcox clays in ever increasing amounts. State severance tax records show that producers reported about 225,000 short tons of Wilcox clay mined in 1949, for use in the manufacture of face brick, fire brick and sewer tile. This represents more than two-thirds of all the clay produced in Arkansas during the year. Since 1943 the U. S. Bureau of Mines has listed the annual production of fire clay from Arkansas and it reports that in 1948 the state produced 273,540 short tons of this material. Figure 3 shows the annual production of fire clay in the state for the period 1943 through 1948, as reported by the Bureau in the "Minerals Yearbook."

Malvern, located midway along the western border of the area described in this report, is the center of fire brick and buff face brick production in Arkansas. Roughly 70 per cent of the Wilcox clay mined in the state comes from two adjacent pits, operated by the Acme Brick Company and the Malvern Brick and Tile Company. This clay deposit is located less than one mile east of the City of Malvern.

The Acme "Perla" plant is situated a short distance north of the Company's pit and the clay is transported to the plant by a narrow gauge railroad. The Malvern Brick and Tile Company's plant is located on the west edge of the city and the clay is hauled two and one-half miles to the plant in dump trucks. Both plants follow much the same procedure in their operation so the description which follows will, in general, be applicable to either Malvern plant.

BRICK MANUFACTURED AT MALVERN, ARKANSAS

By D. H. McKellar

(Engineer, Malvern Brick and Tile Co.)

CLAY USED

The buff brick clay and fireclay deposit is located about one mile east of Malvern, beneath 5 to 10 feet of sandy surface soil and gravel. It is a plastic transported clay, ranging in color from a light pearly grey to a deep chocolate brown, and associated with fine silica sand and a small amount of lignite. The sand is used as an admixture in the manufacture of face-brick and tile; the lignite has not been found in commercial quantities on this property. Thickness of the clay bed varies from ten feet to more than forty feet. The deposit has not yet been mined more than a few feet below natural drainage, but indications are that a substantial reserve of clay will be found if pumping operations ever become necessary.

This clay is mixed with definite proportions of sand and ground brick, or grog, before being made into brick and tile. Such mixtures have excellent drying and burning characteristics, the shrinkage ranging from 3/8 inch per foot for one mix, to one inch per foot for others. The clay is fired to various temperatures from

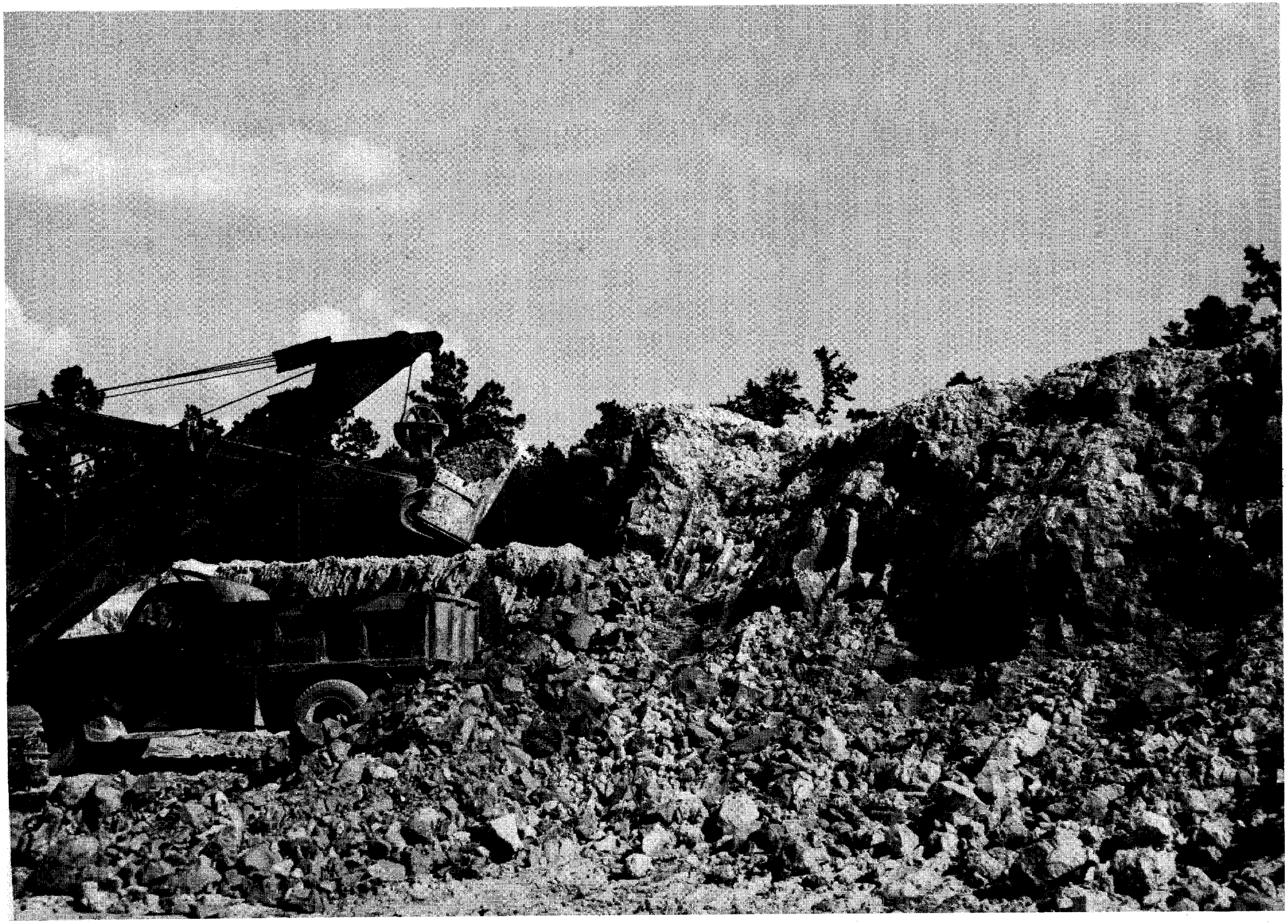


Plate II—Mining a twelve foot clay face in pit of the Malvern Brick and Tile Company, Malvern, Arkansas.

* This photograph was made through the courtesy of the Malvern Brick & Tile Company, by John Blundell, Publicity Division, Arkansas Resources & Development Commission.

cone 9 to cone 13, depending on the type of ware being produced. By careful control of firing cycles and kiln atmospheres, colors ranging from white through a series of clear buffs to a deep reddish brown are produced.

PROCESSING OPERATIONS

All clay mining is done by open pit, using power shovels and dump tracks. Buff clay and sand are stored under a shed having enough capacity for several months' supply.

Grinding and mixing are accomplished in one operation by three dry pans. The clay and non-plastic materials, in measured batches, are ground together as they pass under heavy cast iron mullers in a rotating pan. The ground material is elevated and poured over a vibrating screen, the oversize being returned to the pan for further grinding, and the fines being conveyed to storage bins supplying the forming units.

The ground mixture, generally referred to as "dirt," is formed into firebrick, facebrick, tile, or special shapes by one of the three processes outlined below:

DRY PRESS PROCESS

The dirt from the storage bins, with no water added, is fed into the molds of a heavy mechanical press which subjects it to many tons of pressure, thus changing the loose powder to a compact mass in the shape determined by the mold. Dry press brick may be set directly in the kiln and fired without the preliminary drying operation required in other processes. Malvern Brick & Tile Co. operates two dry press units.

STIFF MUD PROCESS

Dirt from the storage bin is fed into a pug mill, consisting of a series of knives rotating in a trough, where it is tempered with water to the necessary plastic consistency. The pug mill discharges into an auger machine which compresses the mud and forces it through a die to form a column of the desired cross section for the brick or tile being made. This column is then sliced into brick or tile by steel wires stretched across the rotating reel of an automatic cutting machine. Stiff mud ware must be dried before firing. Malvern Brick & Tile Co. operates two stiff mud units.

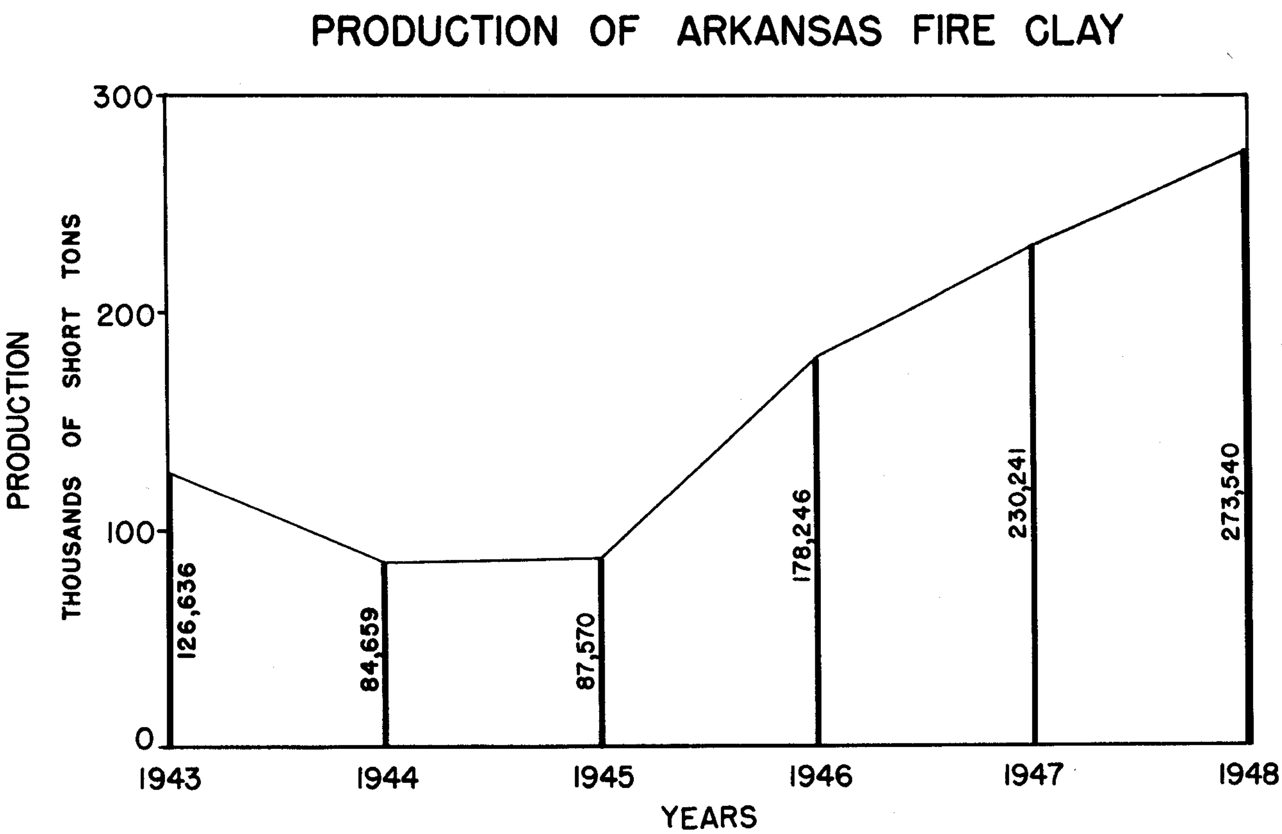
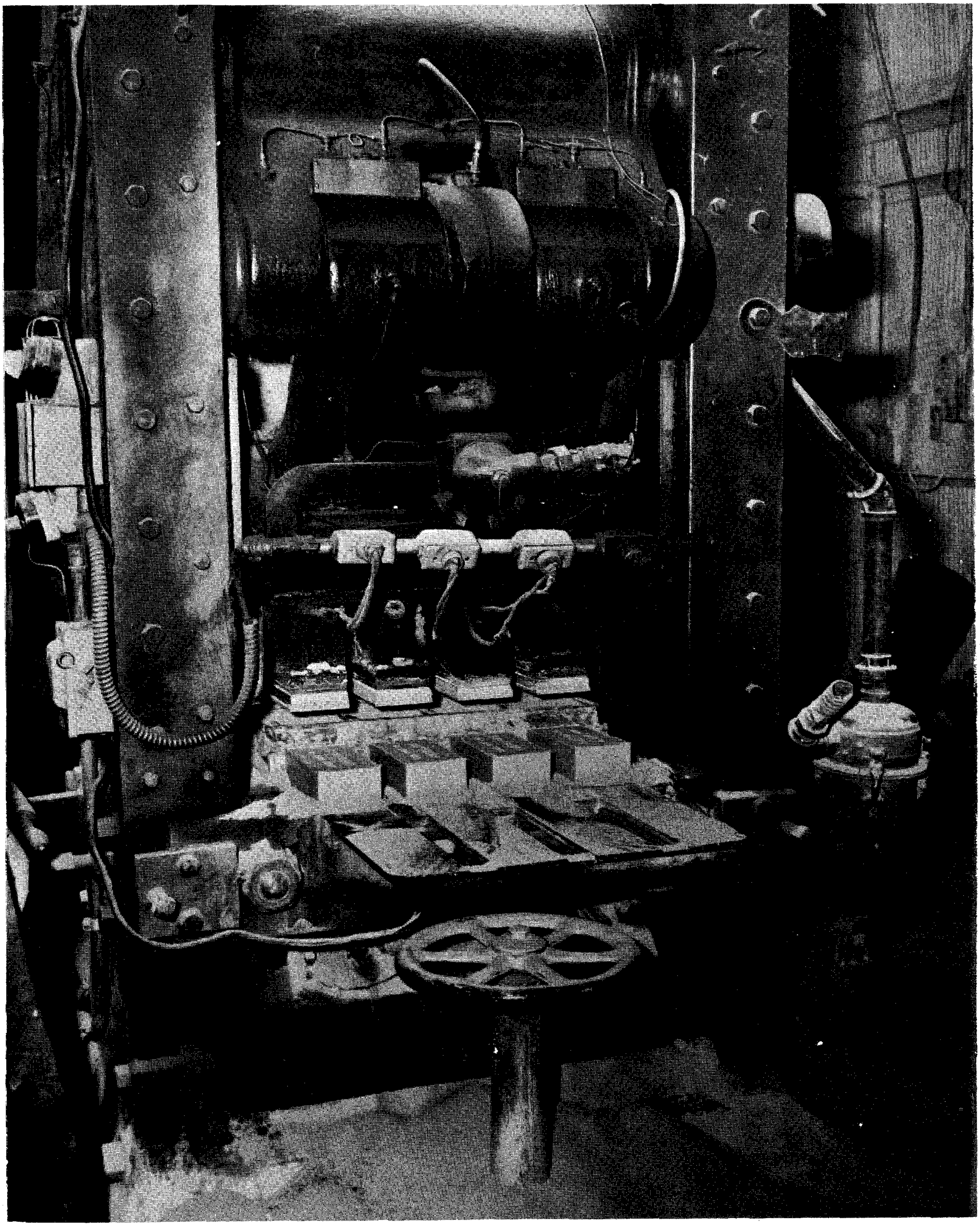


Figure 3. Annual Production of Fire Clay From Arkansas.

* Plate III—Dry pan, used for crushing and mixing clay, grog and sand, prior to forming bricks.

* These photographs were made through the courtesy of the Acme Brick Company, by John Blundell, Publicity Division, Arkansas Resources & Development Commission.



* These photographs were made through the courtesy of the Acme Brick Company, by John Blundell, Publicity Division, Arkansas Resources & Development Commission.

* Plate IV—A dry press used for forming fire brick.

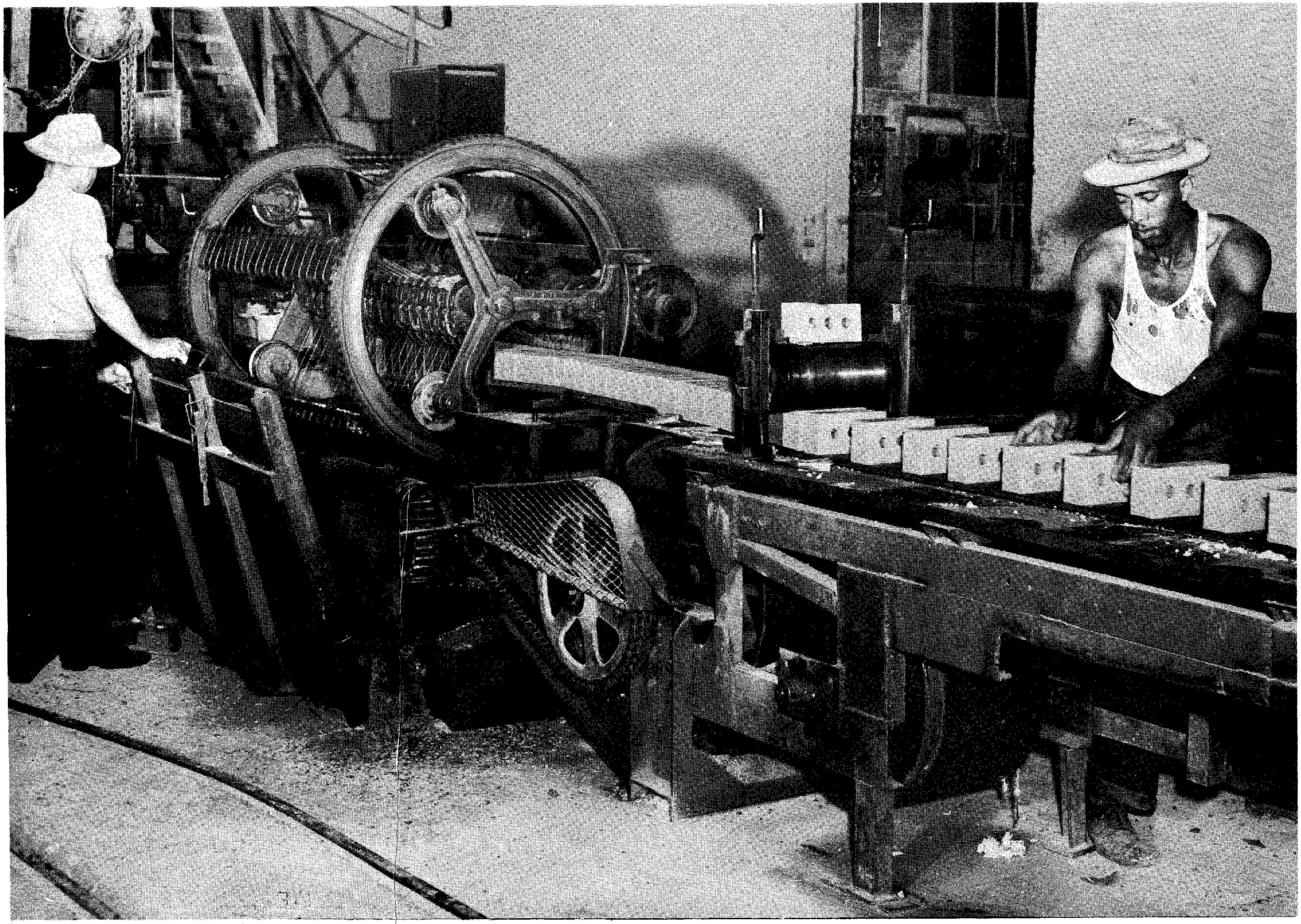
HAND MOLDING PROCESS

The dirt is tempered with water to a soft, easily molded mud which is then forced by hand into wood or steel molds. This process is obviously more expensive than the others, and the ware must be dried slowly and carefully before firing. Only those items which it is not practical to make by machine are made in this way.

Drying and firing equipment consists of eleven round down draft periodic kilns, an eleven-tunnel drier using waste heat from the periodic kilns, and a 200-foot tunnel kiln and drier unit designed by the Allied Engineering Division of Ferro Enamel Co.

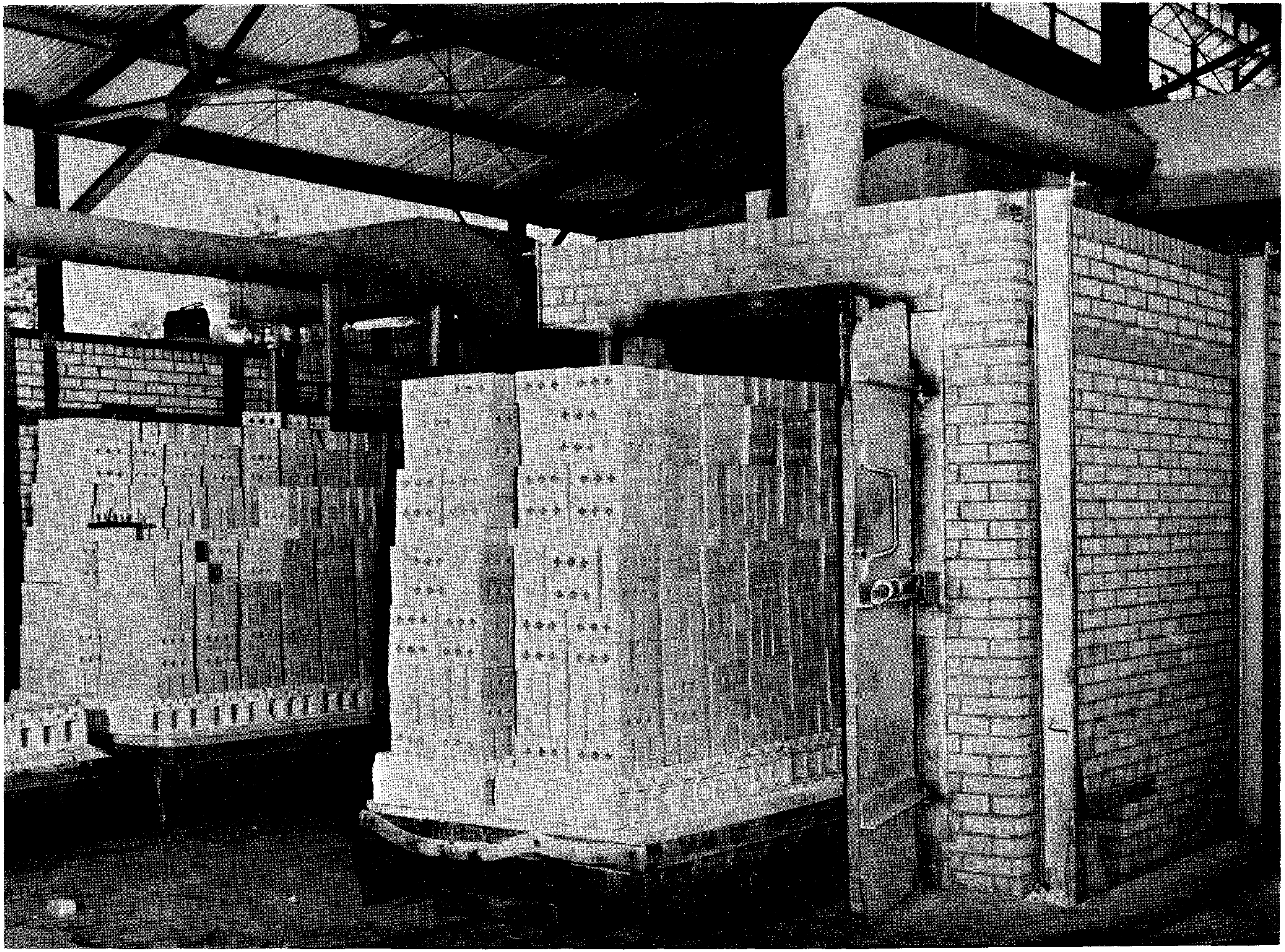
Ware to be fired in the periodic kilns is stacked on 3-foot by 7-foot double-deck steel cars running on 24″ gage track. The loaded cars then pass through the waste heat drier tunnel, remaining in the tunnels for 24 hours to 48 hours. From the drier, the cars are transferred to tracks leading into the round kilns, where the dried ware is set for firing. When a kiln is filled, the doors are sealed and low gas fires lit in the ten fireboxes spaced around its walls. From four to seven days are required to heat kiln and setting to the maturing temperatures of 2200°F. to 2500°F., as indicated by a thermocouple in the kiln crown and by the melting of pyrometric cones set between the brick or tile and observed through peepholes in the kiln doors. After completion of the firing the kiln doors are opened and the setting cooled for several days by a large propeller-type fan. When the ware is cool enough, it is sorted according to color, and moved in specially designed wheelbarrows to freight cars, trucks, or the storage sheds. Continuous daily operation is maintained by having each of the eleven kilns in a different part of its setting-firing-cooling-drawing cycle at any given time.

The tunnel kiln unit effects considerable savings in time and cost over the older periodic system, by application of the principle of continuous flow. Brick to be fired in the tunnel kiln are stacked on six- by seven-foot cars with refractory decks capable of withstanding the high firing temperatures. These cars, after passing through drying tunnels, are then pushed through a 200-foot tunnel in which the brick are progressively heated to the maturing temperature by combustion gases, and then cooled by the air being supplied for combustion. Brick entering the tunnel kiln drier will emerge from the kiln four to six days later, cool enough to be sorted the same day. The hard labor of setting brick in the kiln is eliminated and fuel is saved by the recovery of all the available heat in the burned ware and the flue gas.



* Plate V—Auger and cutting machine used in the stiff mud process of forming brick and tile.

* These photographs were made through the courtesy of the Acme Brick Company, by John Blundell, Publicity Division, Arkansas Resources & Development Commission.



* Plate VI—Loaded car emerging from end of tunnel kiln after firing.

* These photographs were made through the courtesy of the Acme Brick Company, by John Blundell, Publicity Division, Arkansas Resources & Development Commission.

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APPENDIX

(Note: These tables summarize the State Mineral Survey (WPA) data which is included in the body of the report.)

TABLE

Summary of Ceramic Data—State Mineral Survey Test Pits

			PHYSICAL PROPERTIES								FIRED PROPERTIES								
Section	Township	Range	Color	Workability	Water of Plasticity %	Dry Shrinkage Vol. %	Dry Shrinkage Linear %	Modulus of Rupture (sq. in.)	Time of Slaking (Minutes)	Drying Behavior	Cone	Porosity	Absorption	Apparent S. G.	Bulk S. G.	Vol. Shrinkage %	Linear Shrinkage %	Modulus of Rupture (sq. in.)	Color
DALLAS COUNTY																			
15	7S	16W	light brown	fair, not sticky	28.0	41.5	12.27	1005		some warping no cracking	03	23.5	12.6	2.52	1.92	2.6	.87	4202	cream
25	8S	17W	light brown	very plastic, molded well	39.6	40.7	12.05	516	22	some warping no cracking	03	30.1	17.1	2.51	1.76	10.1	3.49	3343	white
											2	29.2	16.4	2.57	1.81	12.5	4.35	5543	white
GRANT COUNTY																			
31	4S	13W	tan	well	21.2	19.3	6.06	276		slight warping no cracking	04	29.7	16.3	2.58	1.82	2.6	.87	1375	red
											2	29.2	16.0	2.58	1.83	1.2	.40	952	buff
											4	25.7	13.8	2.51	1.86	.7	.23	1990	buff
31	6S	14W	tan	good	34.1	41.0	12.13	570		no warping no cracking	03	29.4	16.4	2.53	1.79	5.4	1.84	3803	white
											2	27.6	15.2	2.51	1.82	6.8	2.32	3900	white
											4	13.5	6.5	2.44	2.07	18.6	6.63	6100	buff
32	6S	14W	dark gray	fair coarse & not plastic	37.6	45.9	13.42	713		warping no cracking	04	26.5	14.8	2.43	1.79	4.4	1.49	2600	buff
											2	26.4	14.8	2.42	1.78	4.2	1.42	955	buff
											4	20.6	11.0	2.37	1.87	9.3	3.20	3725	buff
6	6S	15W	cream	good smooth	20.7	15.7	4.98	239		no warping no cracking	03	29.8	16.5	2.55	1.79	1.6	.54	953	white
											2	28.8	15.8	2.53	1.81	.7	.24	1114	white
											4	28.0	15.1	2.56	1.94	1.2	.40	1629	white
6	6S	15W	very light gray	very good very smooth	34.2	39.1	11.63	820		no warping no cracking	4	20.0	12.3	1.74	1.39	2.2	.74	2913	white
18	4S	15W	light gray	stiff but good	31.0	32.4	9.81	373		very little warping no cracking	04	27.7	15.6	2.50	1.80	2.2	.74	2892	white
											2	28.2	15.7	2.50	1.79	2.5	.84	3176	white
											4	26.2	14.2	2.50	1.85	4.8	1.63	3710	cream
23	6S	15W	light gray	good	29.0	39.0	11.60	586		some warping no cracking	04	20.3	10.5	2.43	1.93	5.3	1.80	3830	buff
											2	23.1	12.2	2.46	1.89	4.1	1.39	3270	buff
											4	14.5	7.2	2.36	1.96	10.2	3.52	4742	buff
24	6S	15W	light gray	good fairly plastic	24.3	32.0	9.70	940		slight warping no cracking	2	21.2	11.5	2.37	1.86	.4	.13	2597	cream
											4	17.6	8.9	2.43	1.96	5.8	1.97	3018	cream
27	6S	15W	light gray	soft	35.1	57.1	16.1	1013		considerable warping no cracking	04	13.1	6.4	2.37	2.05	11.0	3.81		cracked buff
8	4S	14W	light brown	stiff crumbled not plastic	33.2	25.1	7.72	152		no cracking no warping	04	37.0	23.4	2.46	1.58	0.5	.17	790	cream
											2	36.0	22.5	2.49	1.60	1.3	.44	997	cream
											4	36.2	22.5	2.53	1.64	2.4	.81	816	cream

TABLE

Summary of Ceramic Data—State Mineral Survey Test Pits (Continued)

Section	Township	Range	Color	Workability	PHYSICAL PROPERTIES: Water of Plasticity %	Dry Shrinkage: Vol. %	Dry Shrinkage: Linear %	Modulus of Rupture (sq. in.)	Time of Slaking (Minutes)	Drying Behavior	FIRED PROPERTIES: Cone	Porosity	Absorption	Apparent S. G.	Bulk S. G.	Vol. Shrinkage %	Linear Shrinkage %	Modulus of Rupture (sq. in.)	Color
16	4S	14W	light gray	good	34.2	50.0	14.47	713		little warping	04	20.3	10.2	2.41	1.92	6.3	2.15	4046	buff
										no cracking	03	30.9	17.3	2.60	1.79	10.7	3.70	3020	buff
											2	20.0	10.2	2.43	1.95	8.0	2.74	1543	buff
31	4S	14W	light gray	coarse	35.6	53.8	15.4	978		some warping	04	22.0	11.6	2.45	1.91	1.6	.54	3572	buff
										no cracking	2	22.1	11.4	2.51	1.95	3.6	1.22	2625	buff
											4	18.2	9.2	2.42	1.99	6.1	2.08	2350	buff
13	4S	15W	light brown	coarse	37.6	33.0	9.97	167		no warping	04	33.1	20.6	2.39	1.60	3.8	1.28	1512	buff
				grainy						no cracking	2	31.0	18.4	2.77	1.68	7.1	2.43	1999	buff
											4	24.6	13.6	2.33	1.79	13.9	4.87	3120	buff
									SALINE COUNTY										
14	2S	15W	tan-pinkish	very plastic	32.2	26.2	8.07	130		irregular warping	03	25.5	13.3	2.51	1.87	12.7	4.4	2109	white
				molded well						no cracking	01	30.9	17.7	2.54	1.75	7.1	2.4	1146	white
											2	25.9	17.1	2.54	1.88	12.9	4.5	3497	buff
											4	17.8	8.4	2.52	2.08	21.2	7.6	2672	buff
											6	16.0	3.4	2.14	2.24	26.9	9.9	3649	buff
											8	2.2	.3	2.23	2.21	27.5	10.2	4305	gray
											10	.4	.2	2.34	2.35	30.2	11.3	2160	
28	2S	12W	light gray	sticky plastic	24.3	28.0	8.58	437	51	regular warping	03	20.0	10.3	2.46	1.96	1.0	.33	1234	buff
			iron-stained	molded well						no cracks	01	17.0	8.2	2.35	1.98	1.8	.60	1203	buff
											2	21.0	9.3	2.46	2.00	1.5	.50	1499	buff
											4	17.1	8.5	2.46	2.01	2.9	.98	1828	buff
											6	16.8	8.2	2.46	2.04	4.4	1.49	2518	tan
											8	15.6	7.3	2.49	2.06	5.5	1.87	2259	tan
											10	17.9	8.8	2.42	2.06	6.0	2.04	2175	tan
											12	13.7	6.6	2.40	2.07	7.5	2.57	2965	tan
3	3S	15W	gray—some	sticky plastic	20.4	9.7	3.13	362		slight cracking	03	28.0	15.5	2.51	1.80	2.0	.67	911	buff
			iron stains	molded well						slight warping	01	28.5	15.7	2.54	1.82	2.4	.80	1175	buff
											2	27.8	15.3	2.52	1.82	.4	.14	1004	buff
											4	25.8	13.9	2.49	1.85	1.9	.30	1421	tan
											6	25.3	13.7	2.48	1.85	2.0	.67	2507	tan
											8	24.4	13.5	2.44	1.84	2.6	.87	2327	tan
											10	22.4	12.0	2.36	1.86	2.7	.90	2211	tan
											12	22.2	12.0	2.38	1.84	2.0	.67	2426	tan
12	2S	15W	light gray—	good	25.7	18.3	5.76	74		warped some	03								
			iron-stained	plasticity						no cracking	01	32.2	18.9	2.51	1.70	.6	.2	304	white
				molded well							2	30.9	17.7	2.54	1.75	3.9	1.3	577	white
											4	28.5	15.9	2.52	1.80	6.2	2.1	1066	white
											6	30.3	11.0	2.53	1.77	4.7	1.6	1428	white
											8	24.7	12.9	2.46	1.86	9.7	3.3	2231	light buff
											10	22.9	12.1	2.44	1.90	10.9	3.8	1918	light buff
											12	21.3	11.2	2.44	1.91	12.1	4.21	2290	light buff

TABLE

Summary of Ceramic Data—State Mineral Survey Test Pits (Continued)

					PHYSICAL PROPERTIES	Dry Shrinkage					FIRED PROPERTIES								
Section	Township	Range	Color	Workability	Water of Plasticity %	Vol. %	Linear %	Modulus of Rupture (sq. in.)	Time of Slaking (Minutes)	Drying Behavior	Cone	Porosity	Absorption	Apparent S. G.	Bulk S. G.	Vol. Shrinkage %	Linear Shrinkage %	Modulus of Rupture (sq. in.)	Color
6	3S	14W	gray-tan	plastic tough	24.0	19.7	6.18	143	120	no warp	03	31.8	17.6	2.66	1.80	2.2	.74	336	buff
			mottled	molded well						no cracking	01	32.0	17.8	2.61	1.79	1.8	.60	316	buff
											2	31.9	17.6	2.67	1.81	1.6	.53	330	buff
											4	31.9	17.6	2.66	1.81	1.1	.37	501	buff
											6	32.5	18.0	2.67	1.80	1.3	.44	444	tan
											8	30.5	16.7	2.58	1.84	.2	.07	722	tan
											10	28.1	15.4	2.56	1.83	.4	.13	565	tan
											12	29.0	15.8	2.57	1.83	.3	.10	710	tan
5	2S	12W	gray	very sticky	24.5	27.8	8.52	262	1 hr.	regular warping	03	24.2	12.6	2.56	1.94	1.0	.33	1408	white
				plastic						no cracking	01	21.5	10.9	2.50	1.96	2.4	.81	1471	white
											2	23.0	11.4	2.57	1.96	2.4	.81	1830	white
											4	20.9	10.4	2.52	1.98	4.8	1.63	1032	light buff
											6	17.3	11.8	2.44	2.01	4.4	1.49	2753	light buff
											8	15.8	7.8	2.46	2.04	6.5	2.22	2591	buff
											10	14.1	7.0	2.38	2.04	5.8	1.97	2450	buff
											12	14.8	7.3	2.39	2.04	6.3	2.15	2877	buff
5	3S	14W	white	medium	2.67	16.2	5.7	123.0	19	no warping	03								
				plastic						no cracking	01	37.1	22.4	2.65	1.66	2.5	.84	234	white
				molded well							2	36.3	21.4	2.66	1.70	2.5	.84	476	white
											4	32.6	18.3	2.65	1.78	8.1	2.1	493	white
											6	31.3	17.6	2.58	1.78	9.3	3.20	847	white
											8	26.2	13.5	2.65	1.94	15.3	5.4	1106	light buff
											10	25.2	12.7	2.61	1.95	16.3	5.8	1353	light buff
											12	24.6	12.5	2.61	1.97	16.6	5.8	1698	light buff
27	2S	14W	cream	poor	33.1	9.4	3.04	23	2½	fair	03	55.8	42.7	2.96	1.31	12.0	4.17	24	white
											01	55.6	42.0	3.03	1.32	14.6	8.13	55	white
											2	55.0	42.3	2.92	1.30	12.1	4.20	37	white
											4	54.8	40.6	3.02	1.36	14.5	5.09	123	white
											6	55.5	41.3	2.99	1.34	14.9	5.24	98	white
											10	45.4	26.9	3.10	1.69	32.8	12.41	551	white
											12	42.1	24.1	3.05	1.76	36.9	14.23	877	white
13	2S	16W	gray to	medium	25.5	11.0	3.54	71	12½	warped regularly,	03	20.8	10.4	2.53	2.01	16.2	5.7	2627	buff
			tan shale	plastic						cracked on	01	14.3	7.4	2.53	2.13	21.2	7.6	3627	buff
				molded well						cross-section	2			2.51	1.98	15.8	5.6	3489	buff
											4	12.5	6.2	2.48	2.15	22.5	8.2	3521	buff
											6	8.8	3.9	2.48	2.24	25.9	8.5	3641	tan
											8	.5	.2	2.29	2.28	27.5	10.1	4666	

TABLE

Summary of State Mineral Survey—Test Hole Data

Frac.	Sec.	Twn.	Rge.	Thickness Overburden (feet)	CLAY Thickness (feet)	Description
				DALLAS COUNTY		
NW NW NW	1	7S	15W	5	19	gray, very plastic clay (very little grit)
NW NE NW NW	1	7S	15W	2	18	gray clay
NE NE NW NW	1	7S	15W	4	16	gray clay
NE NW NE NW	1	7S	15W	2	18	gray clay
NW NE NE NW	1	7S	15W	2	20	light bluish clay & gray clay
CE½ NW¼	2	7S	15W	7	22	gray with little sand & blue clay
SW NW NE	6	7S	15W	2	12	blue & brown clay
CW½ NE¼	6	7S	15W	1	13	blue white, blue & black brown
SE NW NW	6	7S	15W	2	7	1½ ft. soil, 4 ft. white clay, ½ ft. brown clay (white & brown), 2½ ft. white clay, 2 ft. very sandy clay
SW NW NW	6	7S	15W	1	9	1 ft. gravel, 1½ ft. pipe clay, 3½ ft. white clay (white to blue), 4 ft. blue clay, struck gravel
SW SW NE NW	6	7S	15W	0	12	gray to brown plastic
SE NE NW	6	7S	15W	0	14	gray to brown plastic clay
NW SE SE	9	7S	15W	0	10	brown clay
CN½ SW SE	10	7S	15W	3	20	white & brown with lignite
NW SE SW	10	7S	15W	4	12	brown & white
NW SW SW	10	7S	15W	1	23	white & brown lignite
SE SE NW	14	7S	15W	4	24	gray clay, plastic to semi-plastic, gray to light gray, in part slightly sandy
NE SE NW	14	7S	15W	5	16	gray, very slightly sandy
SW SW SW	17	7S	15W	7	14	plastic clay, white at top but darkens to dark blue at 21 ft.
SW NE SE	18	7S	15W	3	8+	White clay darkens with depth, plastic some iron
E½ NW SE	18	7S	15W	3	9+	white clay
NW NW SE	18	7S	15W	3	15+	1 ft. white & 2 ft. blue at top then darkens from white to dark brown at bottom
SW SW SE	18	7S	15W	4	9	white, plastic, with some iron stain
SE NW SE	20	7S	15W	4	15	white, blue & brown, semi-plastic
NE NE NE	21	7S	15W	1	14	white to brown
S½ NW NW	21	7S	15W	2	10	white clay, earthy
NE NW SW	30	7S	15W	0	15	gray to white with lignite
W½ SE SW	30	7S	15W	4	14	dark to medium gray clay, plastic
SE NW NW	31	7S	15W	5	7	dark gray, plastic with lignite at base
SW NE NE	31	7S	15W	5	7	brown to gray clay, plastic
NW SE	32	7S	15W	0	22	light to dark gray plastic clay, some iron stain
W½ NE SW	32	7S	15W	2	15	white sandy clay
NW SE SW	32	7S	15W	3	9	white clay with layer of lignite
SW SE NW	35	7S	15W	1	5	pipe clay

TABLE

Summary of State Mineral Survey—Test Hole Data (Continued)

Frac.	Sec.	Twn.	Rge.	Thickness Overburden (feet)	CLAY Thickness (feet)	CLAY Description
E½ SE SE	5	7S	16W	2	6	pipe clay
NE NE	15	7S	16W	4	10	very sandy white clay, loose to semi-plastic
NW NE	15	7S	16W	4	19	gray, very plastic clay
SE SW NE	15	7S	16W	4	12	very sandy white clay
SL NW NE	19	7S	16W	5	8	white clay
NE NE SE	23	7S	16W	1	12	pipe clay
NW NE NW	4	8S	15W	0	7	gray clay 5% sand
SWC SE SW	4	8S	15W	5	13	gray to brown with lignite
W½ SW SE	5	8S	15W	0	7	gray clay (10-15% sand)
SE NE SE	6	8S	15W	4	9	gray clay (10-15% sand)
C NE	6	8S	15W	0	6	gray clay (5% sand)
C NE	8	8S	15W	0	8	light gray plastic clay
C SW	8	8S	15W	4	5	light brown clay (2-5% sand)
SE	8	8S	15W	5	9	white clay (2% sand)
SE NE SW	11	8S	15W	6	14	gray to brown, no sand
NW NE NW	11	8S	15W	3	6	dark gray clay (5% sand)
CN½ NW	14	8S	15W	8	16	gray to brownish gray (0-10% sand)
NE NW NW	16	8S	15W	6	8	gray clay (2-5% sand)
SE NE SE	16	8S	15W	8	12	gray to brown (10% sand)
NW NE NE	18	8S	15W	6	9	gray to brown with thick lignite beds
SW	31	8S	15W	4	8	gray clay (10-15% sand)
C NE	5	8S	16W	6	8	very slightly shaly gray clay plastic
C SW	12	8S	16W	6	8	gray, plastic, non-sandy clay
C NE	13	8S	16W	4	16	stiff gray clay (5% sand)
NE	13	9S	16W	7	8	gray plastic clay (10% sand)
NW	35	9S	17W	0	6	white clay
				GRANT COUNTY		
CNE	1	3S	13W	1	19	gray, (plastic, 0-1% sand), brown
SE NW NW	2	3S	13W	0	8	white clay (15% sand)
NW NE SW	3	3S	13W	0	8	white clay, plastic (20% sand)
SW NE NE	11	3S	13W	1	8	plastic gray clay (20% sand)
SE NE	13	3S	13W	4	6	gray clay, plastic, no sand
SE NW	13	3S	13W	1	8	gray clay, no sand
C SW	15	3S	13W	8	8	gray clay, no sand
C NE	15	3S	13W	4	21	gray clay, non-plastic (1-5% sand)
NE NW SE	19	3S	13W	1	10	gray clay, plastic (3% sand)
NE NE	19	3S	13W	1	12	gray clay, no sand
SW NW NE	20	3S	13W	1	10	gray clay
SW SE SE	20	3S	13W	5	10	gray clay (2% sand)
NW NE	21	3S	13W	3	11	gray clay, non-plastic, no sand

TABLE

Summary of State Mineral Survey—Test Hole Data (Continued)

Frac.	Sec.	Twn.	Rge.	Thickness Overburden (feet)	CLAY Thickness (feet)	Description
NE SW NE	22	3S	13W	3	10	plastic gray clay, sand
CNE SE	24	3S	13W	3	11	gray clay
SE SE SE	25	3S	13W	1	6	gray clay (10% sand)
SW SW SW	25	3S	13W	4	11	gray clay, plastic, no sand
SE SE	27	3S	13W	3	8	gray clay, plastic, no sand
SW SW	28	3S	13W	1	11	gray clay, plastic, no sand
SE SW	29	3S	13W	2	8	gray clay, plastic, no sand
SE NE SE	31	3S	13W	4	11	gray clay, crumbly (1% sand)
CE½ NE¼	31	3S	13W	3	12	gray clay, plastic (2% sand)
CN½ NE¼	32	3S	13W	2	13	gray clay (10% sand)
CSL SW¼	32	3S	13W	3	10	gray to blue (2-5% sand)
NW NW	32	3S	13W	5	7	gray clay
C NW	33	3S	13W	6	9	gray clay
NW NW	36	3S	13W	0	13	gray to brown
SW SW	36	3S	13W	6	7	gray clay
SW SW	21	3S	14W	1	11	gray clay, plastic (1% sand)
C NW	21	3S	14W	1	8	gray clay (7% sand)
C NE	21	3S	14W	3	6	gray clay, plastic (½-2% sand)
SE SE	22	3S	14W	5	7	gray clay (10% sand), gray to brown (0-10% sand)
C NW	22	3S	14W	2	5	gray clay, no sand
NW NW SE	22	3S	14W	1	14+	gray plastic clay, lignite at base (2% sand)
NW NW	24	3S	14W	1	14	gray clay, plastic (2-5% sand)
C SE	24	3S	14W	5	12	gray to slightly brownish, very plastic, no sand
C SW	25	3S	14W	5	5	gray (5% sand)
SE	25	3S	14W	1	11	gray clay (5% sand)
NE NW NE	27	3S	14W	1	11	gray plastic clay (5% sand)
C SW	27	3S	14W	3	11	gray clay, very plastic (1% sand)
SW NW	28	3S	14W	3	8	gray clay, crumbly to plastic (½-0% sand)
NW SE NE	29	3S	14W	3	8	gray plastic clay (0-2% sand)
SE SE	30	3S	14W	4	6	gray clay, plastic (10% sand)
NW SE	31	3S	14W	4	6	gray clay (5% sand)
SE NE	32	3S	14W	0	9	gray clay (10-0% sand)
NE NE	33	3S	14W	1	9	gray clay (0-5% sand)
C SW NE	33	3S	14W	1	9	gray clay (5% sand)
SW SE NE	33	3S	14W	2	5	gray to brown clay (1% sand)
NW NE	34	3S	14W	2	10+	gray clay (5% sand)
CN½ SW¼	35	3S	14W	3	12	gray clay, plastic (1-5% sand)
SW	36	3S	14W	1	11	gray & brown clay (1% sand)
NW SE NE	35	3S	15W	9	11	blue clay, no sand

TABLE

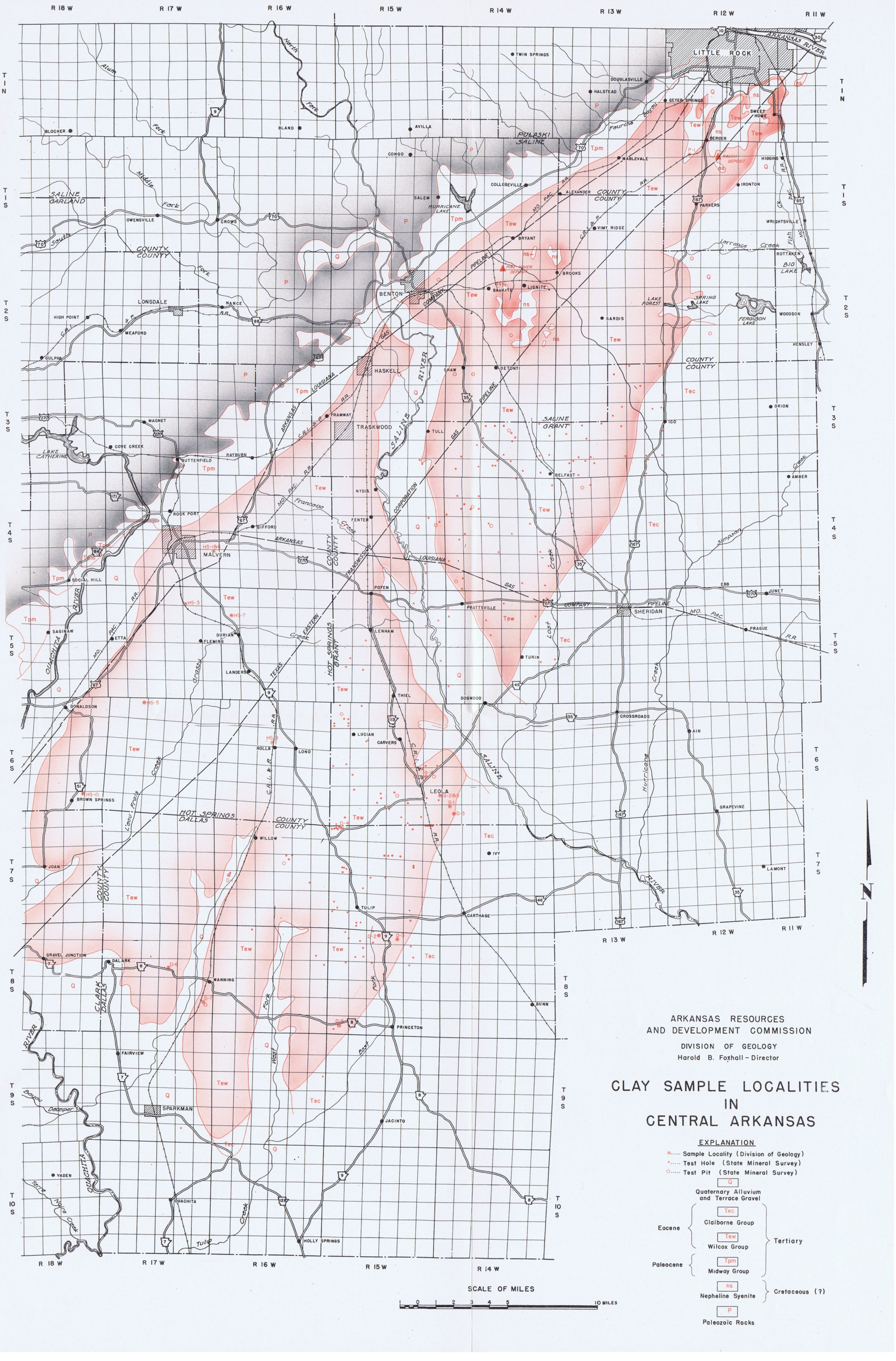
Summary of State Mineral Survey—Test Hole Data (Continued)

Frac.	Sec.	Twn.	Rge.	Thickness Overburden (feet)	CLAY Thickness (feet)	Description
NW NE	35	3S	15W	3	13	gray clay
CEL SE NE	5	4S	13W	0	10	gray clay, plastic (2% sand)
NW SE SE	7	4S	13W	0	10	plastic gray clay (3% sand)
SE NE	1	4S	14W	4	11	gray plastic clay (3% sand)
NE NE NE	3	4S	14W	1	14	gray to brown clay (2-10% sand)
SE SE	5	4S	14W	1	12	brown to gray plastic to non-plastic (5% sand)
SE SW SE	6	4S	14W	7	13	gray plastic clay (2% sand)
SW SW	7	4S	14W	7	8	plastic gray clay (2% sand)
NE SE	7	4S	14W	0	12	gray plastic to brown crumbly (5-10% sand)
SW NW	8	4S	14W	3	18	gray clay, plastic; 2 ft. brown clay, crumbly; 9 ft. gray clay, plastic; with some brown crumbly (5% sand)
NE NE SW	8	4S	14W	4	9+	plastic gray clay (5% sand)
NE SE	8	4S	14W	1	10	gray clay, plastic (2% sand)
NE NW SE	11	4S	14W	1	12+	gray clay (15% sand)
SW NE	14	4S	14W	3	11+	gray clay, plastic (2% sand)
SW SE	15	4S	14W	2	14	dark brown, some gray, no sand
SE NW	16	4S	14W	4	16	gray clay, plastic (5% sand)
SW SW SW	17	4S	14W	1	13	gray, very plastic to crumbly (2-10% sand)
NE	19	4S	14W	1	9	gray plastic clay (3% sand)
SE SE	21	4S	14W	4	6	brown, gray and white, no sand
SW SW	24	4S	14W	4	7†	gray clay, plastic, no sand
NW SE	25	4S	14W	1	8	gray plastic clay (5% sand)
SW NW	30	4S	14W	5	7	gray clay, plastic (10% sand)
SW SE SE	31	4S	14W	3	14	brown & gray, plastic (10% sand)
SL NE	31	4S	14W	11	16	gray plastic clay (2% sand)
NW SW	35	4S	14W	1	10	gray clay (5% sand)
SW NE SW	36	4S	14W	1	17	gray, some brown, crumbly (0-5% sand)
NE SW NE	13	4S	15W	1	10	gray & brown, plastic clay (2% sand)
SE NW NW	13	4S	15W	1	13	gray, plastic to crumbly clay (2% sand)
NE SE	26	4S	15W	6	8	gray, crumbly clay (15% sand)
NE NE	35	4S	15W	1	7	gray clay with brown spots (10% sand)
Center	1	5S	14W	1	7	gray sticky clay (10% sand)
NW SW NE	2	5S	14W	1	15	gray clay, plastic to crumbly (5% sand)
SE NW SW	3	5S	14W	7	9	gray, crumbly clay (5% sand)
SW SW	6	5S	14W	4	12	gray, plastic clay (5% sand)
SW NW	7	5S	14W	1	11	gray clay (5% sand)
NW SW	9	5S	14W	8	8	gray, crumbly clay (2% sand)
SW SE NE	11	5S	14W	7	15	smooth, plastic, gray clay (5% sand)
SE NW	16	5S	14W	5	12	gray, plastic clay (5% sand)

TABLE

Summary of State Mineral Survey—Test Hole Data (Continued)

Frac.	Sec.	Twn.	Rge.	Thickness Overburden (feet)	CLAY Thickness (feet)	Description
NW SW SW	24	5S	14W	2	11	plastic, gray clay (10% sand)
SW NE SE	24	5S	14W	3	8	plastic, gray clay (3% sand)
NW NW	31	5S	14W	1	11	brown & gray clay (10% sand)
SE NW SW	2	5S	15W	1	11	brown clay (15% sand)
SE SE	11	5S	15W	2	9	brown clay (5% sand)
C N½ NW SE	12	5S	15W	1	7	gray, plastic clay (2% sand)
SE NW SE	17	5S	15W	1	6	gray clay (10% sand)
NE SE	19	5S	15W	10	11	brown & gray, plastic clay (2-10% sand)
C W½ SE	24	5S	15W	1	9	brown, plastic clay (10% sand)
C SL W½ NE	29	5S	15W	5	13	gray, plastic clay (5% sand)
NW NE	30	5S	15W	6	12	gray clay (5-10% sand)
NW SW	3	6S	15W	8	12	gray clay (3% sand)
NW NE	5	6S	15W	6	8	plastic, brown clay (5% sand)
SE SE	6	6S	15W	1	8	gray, plastic clay, no sand
SW SW	6	6S	15W	6	16	gray, plastic clay (0-1½% sand)
NW SE	6	6S	15W	4	14	gray clay, no sand
NE NW	6	6S	15W	0	24	brown to dark brown clay, no sand
NE SE	6	6S	15W	5	28	non-plastic, gray to brown clay (1% sand)
NE SE	8	6S	15W	6	19	brown, plastic clay, no sand
NE NE SE	8	6S	15W	0	47	slightly plastic, gray clay (2% sand)
SW SW SW	13	6S	15W	5	19	gray, plastic clay (1% sand)
SW SE	13	6S	15W	5	9	gray, plastic clay (10-20% sand)
SW SW	18	6S	15W	5	10	gray to brown clay (0-5% sand)
Center SE	18	6S	15W	4	11	gray & brown clay (0-5% sand)
SW NW	20	6S	15W	2	12	gray clay (2% sand)
NE NE NE	23	6S	15W	4	11	gray clay (1-5% sand)
NE NE SE	23	6S	15W	1	20	gray clay (2% sand)
Center SE	25	6S	15W	1	17	gray & brown clay (2-5% sand)
NW SW	25	6S	15W	5	23	gray to brown clay (1-5% sand)
SW SW	25	6S	15W	1	8	gray clay (5% sand)
SW SW	26	6S	15W	1	7	brown, plastic clay (1% sand)
SE NW	27	6S	15W	1	11	gray, plastic clay (2-5% sand)
SW NE	28	6S	15W	4	13	gray clay (10% sand)
NW SE	28	6S	15W	1	15	gray, plastic clay (2-5% sand)
SE SW	28	6S	15W	4	13	gray, plastic clay (2% sand)
SE NW NW	29	6S	15W	4	6	gray, plastic clay, no sand
NW NE SE	31	6S	15W	6	10	brown clay (2-5% sand)
SW SE SW	31	6S	15W	1	10	gray clay (3% sand)
NE NE	33	6S	15W	1	18	gray to white clay
NW NE SE	34	6S	15W	1	9	gray clay (2-5% sand)
C W½ NW	34	6S	15W	1	9	gray clay (5% sand)
NE SE	35	6S	15W	1	10	gray, plastic clay (15% sand)
SW SW	35	6S	15W	1	8	gray clay (5% sand)



ARKANSAS RESOURCES
AND DEVELOPMENT COMMISSION

DIVISION OF GEOLOGY
Harold B. Foxhall - Director

CLAY SAMPLE LOCALITIES IN CENTRAL ARKANSAS

EXPLANATION

- Sample Locality (Division of Geology)
- Test Hole (State Mineral Survey)
- Test Pit (State Mineral Survey)

Q — Quaternary Alluvium and Terrace Gravel

Eocene:
- Tec — Claiborne Group
- Tew — Wilcox Group

Paleocene:
- Tpm — Midway Group

Tertiary

ns — Nepheline Syenite — Cretaceous (?)

P — Paleozoic Rocks