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SOME WHITE-WARE AND REFRACTORY CLAYS

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Golden has always been the most important clay-mining district in Colorado. The Dakota fire clays were here mined as early as 1864 or 1865. A year or so later Henry Bell while prospecting for coal found a bed of fire clay and used it in making fire brick. This clay might have come from either the Laramie or Dakota as both of these formations contain fire clay. Some of the clays mined at Golden have been shipped to points east of the Mississippi, but far greater amounts have been used in different parts of Colorado. The finding of fire clay in the Dakota at Golden led to prospecting in other places along the foothills where the Dakota outcropped extensively. The fire clay had been exploited at Platt Canon, Colorado City, and Morrison as early as 1896. The Standard Fire Brick Company of Pueblo worked Dakota clay deposits at Parkdale as early as 1896, and four years later the manufacture of fire brick from Dakota clays was begun at Canon City.

In 1887 clays from Golden were being shipped to Denver and Pueblo potteries and brick yards; six years later brick yards were in operation at Denver, Boulder, and Golden; firebricks were made in Denver, Pueblo, and Golden, and three potteries were in operation in Denver.

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HISTORY OF CLAY-WORKING INDUSTRY IN COLORADO

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The Geijsbeek Pottery Company began making dinner ware at Golden in 1899. This pottery used Colorado raw material exclusively and produced excellent ware which was as

good in color as most of the ware produced by eastern potteries, which were using imported kaolin.

John Herold started the manufacture of china and art pottery at Golden in 1912. In 1915 this plant began to produce chemical porcelain and soon the production of china and pottery was discontinued. Electrical porcelain has been very successfully made but due to the demand for chemical porcelain and the limited capacity of the plant its manufacture was stopped. This plant is now owned and operated by the Coors Porcelain Company.

In the manufacture of chemical porcelain, Colorado clays have been found to burn whiter than English china clay and to have about the same plasticity. The plastic clay used is a fire clay washed free from pyrite and quartz. The flint and feldspar are prepared from Colorado raw material. The second would not class as clays those mixtures which might be plastic but at the same time have a low kaolin content. Neither makes mention of the colloidal material which is present to some extent in all clays.

Ries combines these two definitions obtaining a result which is very satisfactory. His definition is as follows:

"Clay may be defined as an earthy substance of fine texture containing a mixture of hydrous aluminum silicates with fragments of other minerals such as silicates, oxides, carbonates, etc., and colloidal material which may be of either organic or mineral character. The mass possesses plasticity (usually) when wet, and becomes rock-hard when burned to at least a temperature of redness."

DEFINITION OF CLAY

Some definitions of clay make the term very broad including a great variety of substances while others give the terms very definite limits. It is defined by ceramists and potters on the basis of physical characteristics while the geologists' definition is based on origin and composition. These definitions follow in the order mentioned:

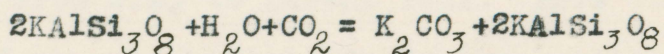
1. A clay is an earthy substance of fine texture which is characterized by plasticity when wet, rigidity when dry, and stoneness when burned to red heat.
2. A clay is a transported or residual deposit composed largely of kaolin, in which the bedding planes or laminations are not well developed. Neither of these definitions is satisfactory. The first would exclude all non-plastic clays, and consequently would throw out some of the best fire clays known. The second would not class as clays those mixtures which might be plastic but at the same time have a low kaolin content. Neither makes mention of the colloidal material which is present to some extent in all clays.

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the process by which the ORIGIN OF CLAYS of the igneous rock to kaolin was accomplished. The finding of feldspar and tourmaline. Clays are products of rock decomposition and thus are always of secondary origin. Rocks that alter most readily to and produce by far the larger part of clay are those containing considerable amounts of sodium and potassium feldspars, but there are other rocks which contain no feldspar, such as serpentine, which produce very good clays. Other rocks, such as gabbros which contain very little feldspar produce on weathering some of the most plastic clays known.

The alteration of feldspar to kaolin and alkali carbonates is an oxidation process which takes place only in the zone of oxidation. This alteration of feldspar is called kaolinization. The chemical reaction may be represented by the equation:



In some places kaolinization seems to have been carried on not by the ordinary process of decomposition but to have been brought about by hot mineralizing vapors and solutions. Kaolin produced by hot vapors is termed kaolinization by pneumatolysis, and that produced by hot vapors and water combined, kaolinization by pneumatohydrogenetic processes.

At Cornwall, England pneumatolysis seems to be

RESIDUAL CLAYS

the process by which the alteration of the igneous rock to kaolin was accomplished. The finding of fluorspar and tourmaline and also the unlimited depth to which the alteration took place indicate the presence of hot vapors. At Zettlitz, Bohemia conditions suggest kaolinization by the same process.

Residual clays produced by weathering of an igneous rocks composed chiefly of feldspars will grade into the parent rock at no great depth. Weathering in this case has begun at the surface and worked downward for long periods of time, during which very little if any of the products of weathering were carried away by means other than solution. Clays of this kind will contain quartz and mica which can be removed by washing. The kaolins of North Carolina, Delaware, and Pennsylvania are the result of the weathering of the feldspathic rock to depths varying from sixty to one hundred twenty feet.

In the case of residual clays resulting from the decomposition of limestones and dolomites there is no gradual transition from clay to parent rock. Here the clay is a result not of the alteration of aluminum silicates but of the concentration of insoluble impurities by the removal of calcium carbonate.

The shape and form of residual clay deposits depends upon the shape of the parent rock. Where the kaolin is the result of the weathering of a pegmatite dike the deposits will be in the form of veins the same width as the dike, but the depth to which the weathering extends depends upon the length of time of weathering and the access which the agents of alteration have had to the dike. In places where large bodies

RESIDUAL CLAYS

A residual clay is one which is found overlying the rock from which it was derived.

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of highly feldspathic rock are exposed the kaolin resulting from alteration takes the form of a mantle which may extend to one hundred feet or more in depth. In places where weathering has taken place along a fissure or a fault as in Cripple Creek the deposits are of the vein type. If the kaolinization has been accomplished by pneumatolysis as in England and Bohemia there is no known limit to the depth of the deposit. The rate and depth of weathering will depend upon the character of the rock and the climate. If it is a coarse grained rock in a moist climate it will weather more rapidly than a fine grained rock in a dry climate. by the place and conditions of deposition, and by observing the characteristics of the beds they may be divided as follows:

Marine clays are those which are deposited on the sea floor in quiet water at some distance from shore. Clays of this type are usually of vast extent and great thickness but are variable laterally and usually vertically.

Estuarine clays are those clays deposited in shallow inlets and arms of the sea. Deposits of this kind are usually basin shaped with the fine clay toward the sea end. They often show sandy laminations and are not as completely sorted as clays deposited in the sea.

Swamp and lake clays are deposited in shallow depressions occupied by swamps and lakes. Clays of this class are usually very impure, and are used only for common brick and earthenware.

Flood-plain and terrace clays are those which are

TRANSPORTED CLAYS

Clays which have been formed by primary rock decomposition carried some distance by water, wind, or ice, and deposited, are called transported clays. Final deposition may take place in lakes, streams, seas, or on the land, depending upon the transporting agent and the rate of movement. The coarse material will be deposited as soon as the rate of speed of the transporting agent is decreased to a slight extent, while it may take days for the finest material to settle out of the medium after all of the motion has ceased.

Sedimentary clays are influenced by the place and conditions of deposition, and by observing the characteristics of the beds they may be divided as follows:

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Flood-plain and terrace clays are those which are

deposited along the banks of streams in times of high water. Clay of this kind is usually sandy with many impurities finding use only in common brick and tile.

In the following pages are given the properties and uses of the different kinds of clays. Since the purpose of this investigation was to discover clays which might be used in the manufacturing of white-ware, china, porcelain, and refractories, more space will be given to the description of these clays than to those of poorer quality.

CHINA CLAY OR KAOLIN

This is used to designate those white-burning residual clays, which are composed mostly of silica, alumina, and combined water. The name kaolin is a corruption of the Chinese Kauling which means high ridge and is the name of a hill near Jauchau Fu, where the mineral was obtained for making china. After careful washing and refining kaolin approaches the composition of the mineral kaolinite. This fact has led many to believe that kaolins are composed chiefly of kaolinite, but chemical analysis often shows a higher alumina-silica ratio than is required for kaolinite. The high alumina-silica ratio can be accounted for on the supposition that some other hydrous aluminum silicate, such as halloysite, phlogopite, or allophane, are present. Rice thinks that in addition to these hydrous silicates high in alumina there is present the aluminum hydroxides bauxite and gibbsite.

White mica or muscovite, which resembles kaolinite in chemical composition may be present in amounts as large as

KINDS OF CLAYS, THEIR PROPERTIES AND USES.

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White mica or muscovite, which resembles kaolinite in chemical composition may be present in amounts as large as

BALL-CLAY

in chemical composition may be present in amounts as large as twenty per cent. This mineral is not refractory; thus it is probable that those kaolins, which are not highly refractory, carry high percentages of muscovite.

The physical properties characteristic of kaolin are low air-shrinkage, low tensile strength, white-burning, and usually high refractoriness. The following tests bring out these points well, and show great variation in some of the properties:

1. Kaolin from Harris Clay Company, Webster, N.C., works up with 42 per cent of water to a lean mass. Air-shrinkage, 6 per cent; fire-shrinkage at cone 9.4 per cent; average tensile strength, 22 pounds per square inch; fuses about cone 33.

2. Kaolin from Glen Allen, Mo.--Requires 23.2 per cent of water to work it up to lean paste whose air-shrinkage is 4 per cent and fire-shrinkage, at 2500°F., is 8.4 per cent; average tensile strength, 12 pounds per square inch; incipient fusion 2200°F.; vitrification at 2500°F.

3. Kaolin, Oak Level, Henry county, Virginia.--Water required 48.4 per cent., plasticity and tensile strength low; air-shrinkage 1.6 per cent; fire-shrinkage, cone 9.8 per cent, with absorption 36.08; fusion point above cone 27.

Kaolin when mixed with different proportions of flint and feldspar is used in the manufacturing of white-ware, china, and chemical and electric porcelain.

BALL-CLAY

Vitrification.--Should not take place below cone 10.
 Color Burned.--White or slightly yellow.

Ball-clay includes those white-burning plastic clays of sedimentary origin which are used as a necessary ingredient to give the body plasticity and tensil strength. The content of iron must be low, and refractoriness while desirable is not a necessity as some of those which are imported vitrify at cone 8.

The physical properties of some of the well known and much used ball-clays in this country are:

Edgar, Florida.--Very plastic, average tensil strength, 150 pounds per square inch; total shrinkage at cone 9, 15 per cent.

Woodbridge, N. J. --Water required, 33 per cent, plasticity, fair; air-shrinkage, 3.4 per cent; average tensil-strength, 33 pounds per square inch; at cone 10, fire-shrinkage 16.6 per cent, and absorption 0.22 per cent; fusion-point, cone 34.

The following tabulation gives the properties which an ideal ball-clay should possess.

Texture.--Should be fine.

Color Unburned.--Should be white or gray.

Impurities.--Anything except white mica and a little quartz and feldspar.

Plasticity.--Should be very fine.

Cohesion.--Should be high.

Tensil Strength.--Well over 100 pounds per square inch.

Vitrification.--Should not take place below cone 10.

Color Burned.--White or slightly yellow.

Chemical Character.--Ferric oxidized not much over one per cent, and fluxes scanty.

Washing is often employed to remove impurities, as at Coors Porcelain Company where a washed fire clay is used as a ball-clay.

Tablets, which may be decorated with relief or painted designs. They are glazed on one surface with colorless or colored transparent glaze.

Clay for wall-tiles should have the following properties:

Texture.--Should be fine or grinding is necessary.

Impurities.--No visible impurities except quartz and feldspar.

Cohesion.--should be high.

Fire Shrinkage.--should not be much over eight per cent.

Chemical Character.--Should not contain much over one per cent iron oxide.

Warping, cracking, blistering, or swelling is not permissible.

Impurities may be removed by washing.

WALL-TILE CLAY

Wall-tiles are made of white-burning clay, and are not burned to vitrification but are usually just hard enough to resist scratching with a knife. It is therefore very porous. The tiles molded in dry press machines are rectangular tablets, which may be decorated with relief or painted designs. They are glazed on one surface with colorless or colored transparent glaze.

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Impurities.--No visible impurities except quartz and feldspar.

Cohesion.--Should be high.

Fire Shrinkage.--Should not be much over eight per cent.

Chemical Character.--Should not contain much over one per cent iron oxide.

Warping, cracking, blistering, or swelling is not permissible.

Impurities may be removed by washing.

Plasticity.--Should be fine.

Cohesion.--Should be strong.

Water of Maximum plasticity.--Should be low.

Air-shrinkage.--about six per cent is the maximum.

Allowable Cracking in Air.--None.

WHITE-WARE CLAY

White-ware includes those products having a white, or nearly white porous body which is usually covered with a glaze. There are several trade varieties of this ware known as C.C. ware, white granite ware or ironstone china, semi-vitreous ware, semi-porcelain and china. Some of these products differ at times in name only. Theoretically they differ in the degree of whitemess and vitrification. Domestic utensils such as cheap dishes, wash-bowls, and pitchers, and some sanitary-ware are in this class. This kind of ware is usually made from mixtures of kaolin, ball-clay, quartz, and feldspar, but clays which are neither ball-clays or kaolins are used with the amounts of flint and feldspar which are necessary to give a certain composition. The pieces are burned to incipient vitrification and then glazed and reburned. Soft glazes containing borax and lead oxide, which mature at low temperatures, are used. Clays which are suitable for white-ware will have the following properties:

Texture.--Should be fine.

Color Unburned.--White or gray.

Impurities.--Anything in visible amounts except quartz and feldspar.

Plasticity.--Should be fine.

Cohesion.--Should be strong.

Water of Maximum plasticity.--Should be low.

Air-shrinkage.--About six per cent is the maximum.

Allowable Cracking in Air.--None.

Tensile Strength.--Should be 150 pounds or more per square inch.

Vitrification.--Should be several cones above incipient vitrification; usually above cone 10.

Color Burned.--Perfectly white.

Fire Shrinkage.--Six per cent is about the maximum.

Chemical Character.--Iron oxide should not exceed one per cent; total fluxes should be less than five per cent.

Warping, swelling, checking, cracking, or blistering are not permissible.

Washing may be used to remove undesirable impurities and other clays and ingredients may be added to remedy deficiencies in certain properties. Many clays may be used which do not possess the given properties because the certain ware being manufactured may not demand them.

Great care should be used in selecting clay for floor-tile as no cracking, splitting, or warping can be permitted. The clays must also be free from soluble salts.

Floor-tile, when white, are usually made of a mixture of white-burning clay, flint, and feldspar. Colored tiles are made from clays or shales which burn to attractive colors or from light colored bodies to which a coloring material has been added.

There are many kinds of clay used in floor-tile but the following properties are desirable:

Texture.--Should not contain pebbles.

Color.--Must be white or gray for white-tile.

Impurities.--No soluble salts.

Vitrification FLOOR-TILE CLAY several cones above incip-

ient Vitrification and at least eight cones below viscosity, if the tiles are vitrified. These properties are necessary for a variety of colors made from clay, feldspar, and flint mix-

tures. On account of the condition under which they are used they should possess sufficient hardness to resist abrasive action, sufficient transverse strength to resist knocks, and sufficient density to prevent excessive absorption.

Floor-Tiles: These have a carefully selected clay mixture for the face of the tile backed by a cheaper clay of the same air and fire shrinkage.

Tesseraï: In this group the whole tile is made from the same body.

Encaustic Tiles: This term is used to designate a tile of varicolored patterns, produced by carefully placing in the mold, masses of clay which burn to different colors.

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There are many kinds of clay used in floor-tile but the following properties are desirable:

Texture.---Should not contain pebbles.

Color.---Must be white or gray for white-tile.

Impurities.---No soluble salts.

Vitrification.--Should be several cones above incipient vitrification and at least eight cones below viscosity, if the tiles are vitrified. These properties are necessary for a hard tough product.

Color Burned.--Pure white for white tiles and attractive tints for colored ones.

Fire Shrinkage.--Should be less than eight per cent.

Absorption.--Maximum allowable, eight per cent.

Warping, cracking, blistering, checking, or swelling, is not permissible.

Washing may be employed but it usually is unnecessary except for white-burning clay.

1. Plastic Fire-Clay: Those clays which have a plasticity of fair or better.

2. Semi-plastic Fire-Clays: Those clays which have a plasticity which is less than fair.

3. Flint Fire-Clay: Those clays which have no plasticity.

Fire-clays are usually classified according to their fusion points.

No. 1. Fire-Clay or Highly Refractory Clay: Fuses above cone 33.

No. 2. Fire-Clay or Refractory Clay: Fuses between cone 31 and 33 inclusive.

No. 3. Fire-Clay or Semi-refractory Clay: Fuses between cone 27 and 31 inclusive.

This classification is well known and wide used, and will be the one followed in this report.

REFRACTORY CLAYS

Refractory ware included all fire clay articles such as fire-brick, crucibles, muffles, stove linings, glass pots, pyrometer protection tubes, and retors, which will stand a temperature of at least cone 27 without becoming viscous. In addition to the fusion point the absorption must be low when the ware is exposed to corrosion as in crucibles, blast-furnace linings, glass pots, and zinc retorts; but when the products are used for purposes where sudden changes of temperature take place the absorption should be high.

Fire-clays are classed according to their plasticity:

1. Plastic Fire-Clay: Those clays which have a plasticity of fair or better.
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Fire-clays contain practically all the substances usually determined by ultimate analysis, but in every good fire-clay the total percentage of the fluxing impurities, such as ferric oxide, lime, magnesia, and alkalies, is small. Quartz will also reduce the refractoriness if present in excessive amounts.

It has been found by experiment that a certain kaolin having a fusion point of 1820°C ., when mixed with different amounts of quartz had a eutectic point at 1630°C . The corresponding eutectic mixture was kaolin 10 per cent and quartz 90 per cent. A slight increase in quartz and decrease in kaolin caused an abrupt raise in the fusion point of the mixture; but when the kaolin was increased and the quartz decreased there was a gradual raise in the fusion point. Experiments show that the fusion point is decreased, on an average, of one cone for every 10 per cent of quartz added to the kaolin.

Analysis of fire-clays fusing at cone 34 showed free silica less than 14 per cent and two fusing at cone 27 showed free silica above 40 per cent.

The physical properties of fire-clays are not used as a guide to their refractoriness. However color may at times be an aid, as pure white or light yellow clays might be expected to be at least semi-refractory, but it also happens that deep yellow and yellowish red clays may be very refractory.

Plasticity has little or no direct relation to re-

explanation of the difference in behavior of the two clays is that the low refractory clay burns to a dense body at a comparatively low temperature thus closing the pores and preventing the molten material from permeating the mass, while the molten material readily permeates the higher and more porous refractory.

Fire-clays are of variable tensile strength. Some of the highest refractories show the lowest tensile strength, but this may be remedied by blending with another more plastic clay at a slight loss of heat resisting qualities.

High air and fire shrinkage may be overcome by the addition of grog in the form ground fire-brick-bats or calcined fire-clay.

CLASSIFICATION OF CLAYS

There are many classifications of clays in use today. They are based on origin, occurrence, fusibility, uses, chemical composition, & certain physical property, and various combinations of their characteristics and properties.

The classification of Rie's which is based on fusibility has the widest use from the industrial standpoint and is very satisfactory. The classification follows:

1. High Refractory or No. 1. Fire Clay: Fuses above cone 35.
2. Refractory or No. 2. Fire Clay: Fuses between cones 31 and 35 inclusive.
3. Semi-refractory or No. 3. Fire Clay: Fuses between cones 27 and 31 inclusive.

CLAYS USED IN UNBURNED CONDITION

5. Non-refractory clays; fuses below cone 20.

The classification of Grinsley and Grout based on

Paper Clays.--These clays are used by paper manufacturers as a filler and in finishing. Clays for this purpose must be pure white in color, very plastic, and extremely smooth and fine grained. Usually the clay used for this purpose is the very best grades of washed plastic kaolin.

Ultramarine Clay.--Clay is used in the manufacture of ultramarine to serve as a nucleus for gathering the coloring material. This use demands a very fine textured washed kaolin or white sedimentary clay which is low in iron, lime, and silica.

CLASSIFICATION OF CLAYS

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5. Non-refractory Clays: Fuses below Cone 20.

The classification of Grinsley and Grout based on origin and refractoriness is the one which will be used in this investigation. It is as follows:

I. Residual clays.

1. Kaolin.
2. China--or Porcelain-clay.

II. Transported clays.

A. Refractory (fluxing impurities low).

3. Flint fire-clay.
4. Plastic fire-clay.

B. Semi-refractory clay. (fluxing impurities medium).

5. Paving-brick clay or shale.
6. Sewer-pipe clay or shale.
7. Stoneware-clay and shale.

C. Non-refractory (fluxing impurities high).

8. Pottery clay.
 - a. Ball-clay.
 - b. Fower-pot clay.
9. Brick-and tile-clay and shale.
 - a. Ornamental brick-clay and shales.
 - b. Terra-cotta clay and shales.
 - c. Ornamental tile-clay.
 - d. Common-brick-and tile-clay.

10. Gumbo ballast-clay.

11. Slip clay.

DESCRIPTION OF CLAY-BEARING FORMATIONS

The following descriptions of the different geological formations are general and incomplete. They are given with the idea that they will serve to locate certain clay-bearing horizons and aid the prospector in his search for the higher grades of clay.

McELMO FORMATION

The McElmo formation is a series of alternating beds of sandstones and shales probably Jurassic age, from five hundred to nine hundred feet in thickness. The sandstones are pink, maroon, green and white, and vary in thickness from less than a foot to twenty feet or more. Near the top of the formation they are often conglomeratic; but lower in the series they are more often of an even sugary grain showing much cross bedding. Some of the sands are firmly cemented while others are very friable. The shales are pink, green, maroon, chocolate brown, and brownish red in color, and range in size from shaley partings to beds eighty feet in thickness. The shales vary greatly in character and color. Some are very plastic and soft while others are hard and flinty. The color within a foot either vertically or horizontally may change from a light green to a dark maroon, or chocolate brown.

This formation contains bentonite which might be used as a decolorizer and diodorizer, but no clays suitable for refractory ware, dishes, and porcelain have been found.

MANCOS FORMATION

The Mancos formation consists of slate-colored to drab shales with thin beds of lime stone and shaley sandstone. The shales are continuous little variation taking place along a single horizon. This formation gives little promise of yielding any clays suitable for white-ware and porcelain.

MESA VERDE FORMATION

The Mesa Verde formation is composed of massive sandstones with interbedded sandy shales and many beds of coal and carbonaceous shales. The massive sandstones are medium to coarse textured and are in places cross-bedded. They commonly weather to a variety of shades usually reddish or yellowish brown. The rock is not resistant but weathers readily probably due to calcium carbonate or alkali cement. The shales are in general lighter in color and more sandy than those of the Mancos. The coal occurs largely in the lower half of the formation in beds from a few inches up to twenty-five feet in thickness.

Clay from this formation burns to a light grayish white with tinges of buff. Further examination of this formation is necessary to determine the quality of clay which it contains. These clays have not only been used for refractory ware, but have found uses in electrical and chemical porcelain.

MORRISON FORMATION

The Morrison is from two hundred feet to two hundred and fifty feet in thickness consisting of alternating sandstone, limestones and shales which are white, greenish-gray, gray-red, maroon, and buff in color. The lower part is composed chiefly of alternating beds of sandstones and shales while the upper part is made up of limestone and shale. The formation varies greatly in relative amounts of shale, limestone and sandstone.

No clays which might be used for the manufacture of higher grades of pottery have yet been found in this formation, but the recent discovery of a nearly white-burning plastic clay invites further investigation.

DAKOTA SANDSTONE

This formation is a fresh-water deposit composed chiefly of brownish yellow to white sandstone with several beds of clay which vary in thickness, from a few inches to over twenty feet. The clays usually carry carbonaceous material, which produces the dark gray and black color of the clays.

It is safe to say that this formation has produced a larger amount of high grade refractory clay than any other in the state. These clays have not only been used for refractory ware, but have found uses in electrical and chemical porcelain.

ARAPAHOE FORMATION

The Arapahoe formation is of the same age as the lowest part of the Dawson, and may be traced into the base of that formation. At the base of the Arapahoe are conglomerate beds containing some coarse sandstone, which taken together make a thickness of fifty to two hundred feet. The color is usually light gray or white. Above the basal conglomerate lies four hundred to six hundred feet of fine friable sandstone, sandy clay, and clay. The characteristic color is light gray with pinkish tinges in places. Carbonaceous zones and patches are not uncommon.

The beds of clay at Golden, have been extensively worked, and are producing at the present time.

DAWSON FORMATION

The Dawson formation is the lower member of what was called the Monument Creek group. It has a maximum thickness of about two thousand feet and covers a large area east and northeast of Colorado Springs. The sediments consist of an alteration of grits, sandstones, conglomerates, sandy shales, and clays. The color is in most places light gray or grayish white, but beds of pink, red, yellow, and brown sediments occur. The beds in some places are unconsolidated and will crumble easily, but in others they are very firmly cemented. In some localities the formation shows no bedding or sorting, but in others cross-bedding is very characteristic, and the stratification planes are very

well defined. The clays are usually massive with large blotches of pink and yellow stain occurring at random through the gray or grayish white beds.

With the exception of the Dakota the Dawson is the most promising clay producing formation in the state. Many mines have been opened at Calhan and also at Castle Rock and Larkspur. The clay at Calhan has been used for refractory-ware and stoneware, but with proper washing and purification it could be used for higher grades of clay products.

RATON FORMATION

The thickness of the Raton formation south of Trinidad is two thousand five hundred feet, thinning to eight hundred feet on the eastern outcrop and to one thousand feet on the northern outcrop. The lower two hundred feet is made up of thin beds of greenish gray fine grained sandstone separated by thinner layers of light to dark gray shales. Coal and dark beds of shaley clay also occur in this basal member. Dark brown calcium carbonate concretions seamed with brown siderite veinlets are found in these lower beds. The remainder of the formation increases in sandstone and decreases in shale and coal toward the top.

The large number of clays collected from the Raton formation show no properties which would warrant further search for high grade clays in this formation.

VERMEJO FORMATION

The sediments, which lie between the basal conglomerate of the Raton formation and the Trinidad sandstone, are referred to by Willis T. Lee in Professional Paper 101 of the United States Geological Survey, as the Vermejo formation. These beds vary in thickness from fifty feet at San Francisco Creed to two hundred one feet at Aguilar, and are composed of alternating beds of shale, coal, and sandstone from less than a foot to over thirty feet in thickness. The character of the sediments changes very rapidly making any single bed hard to follow even for short distances.

Samples of clay from this formation do not have the properties which are characteristic of high grade clays.

In collecting the clays the location was fixed as exactly as possible, the township, range, section, and quarter-section were recorded whenever it was possible to determine them.

The name and age of the formation from which the clay was taken were always determined and a full description of the clay beds was made. The field description of the clay included structure, texture, hardness, color, visible impurities, fracture, and remarks.

Since the different degrees of hardness and texture are terms which do not convey the same meaning to everyone, the following scales for them were adopted, and used in all of the field descriptions:

COLLECTING OF CLAY SAMPLES

Very fine: No grains visible in groundmass with

The clay samples which have been tested in this investigation were collected in the fall of 1922 and the summer of 1923. The parts of the State which seemed to offer the most promising clay-producing localities were visited. The counties in which the clay deposits were sampled are, Mesa, Delta, Baca, Powers, Bent, Las Animas, Huerfano, Otero, Pueblo, Custer, Freemont, El Paso, Douglas, Jefferson, Boulder, and Larimer. Of these counties only Mesa, Delta, Baca, Powers, Bent, Otero, and Las Animas have been thoroughly explored for high grade clays. In the remaining counties only those formations and localities which were known to contain commercial clay deposits were examined.

In collecting the clays the location was fixed as exactly as possible, the township, range, section, and quarter-section were recorded whenever it was possible to determine them.

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Since the different degrees of hardness and texture are terms which do not convey the same meaning to everyone, the following scales for them were adopted, and used in all of the field descriptions:

Texture. --

Very fine: No grains visible in groundmass with aid of lens.

Fine: Finely granular under lens, and grains visible to unaided eye.

Medium: Grains easily visible to unaided eye.

Coarse: Grains visible to eye at first glance.

Very Coarse: A grain like sugar.

Hardness. --

Very soft: Easily shoveled.

Soft: Shoveled with difficulty.

Medium soft: Shoveled with great difficulty.

Medium hard: Must be picked.

Very hard: Almost as hard as stone.

Ball mill: The ball mill consists of a porcelain jar, a rack for rotation, and twenty five pounds of flint pebbles. It will grind fifteen pounds of clay at a time to any mesh desired.

CLAY WORKING APPARATUS

Pug mill: This machine (Fig.1.) is used to mix and work the air out of clay. The dry clay mixture and water are fed in at the top of the machine; revolving blades mix the clay and force it out through the opening at the bottom.

Auger: The auger machine (Fig.2.) is used to make articles such as brick and roofing tiles, by forcing stiff-

LABORATORY EQUIPMENT

The laboratory equipment consists of four classes of machinery: grinding equipment, clay working machinery, burning apparatus, and special testing apparatus.

GRINDING EQUIPMENT

Dry and wet pan: This machine (Fig.1.) is used for reducing very coarse material to six mesh. Pieces as large as common brick may be fed directly to this machine. It accomplishes the grinding by two wheels, which weigh 350 pounds each, riding on the floor of a revolving pan, on which the material to be ground is thrown.

Jaw crusher: This small crusher is used to reduce clay to one-fourth inch. When small amounts of clay are to be ground it is first put through this crusher.

Ball mill: The ball mill consists of a porcelain jar, a rack for rotation, and twenty five pounds of flint pebbles. It will grind fifteen pounds of clay at a time to any mesh desired.

CLAY WORKING APPARATUS

Pug mill: This machine (Fig.1.) is used to mix and work the air out of clay. The dry clay mixture and water are fed in at the top of the machine; revolving blades mix the clay and force it out through the opening at the bottom.

Auger: The auger machine (Fig.2.) is used to make articles such as brick and roofing tiles, by forcing stiff-

mud through a die by means of a screw device. The stiff-mud is fed into the top of the machine and is forced through the die which is placed over the opening on the left end.

BURNING APPARATUS

Pottery kiln: This (Fig.3.) is an oil-burning muffle kiln. The kerosene is vaporized and drawn up into the kiln by natural draft and burned in fire clay tubes around the sides of the muffle. It has been found that jets of compressed air at twenty pounds pressure applied at the bottom of the kiln greatly increase the temperature and decrease the consumption of oil. Temperatures as high as cone ten, $1330^{\circ}\text{C}.$, have been obtained in this kiln.

Fusion furnace: This furnace (Fig.4.) is a steel cylinder lined with high refractory material. The fuel used is gas which is mixed with air and fed to the furnace by a high-speed motor blower. The inside dimensions of the furnace are seven inches in diameter by twelve inches in height. The fusion tests are enclosed in a high-refractory crucible to prevent the burning gases from coming in contact with the pyrometric cones. The crucible is set on a stool in the center of the furnace about two inches above the bottom. Temperatures as high as cone 36, $1850^{\circ}\text{C}.$, have been attained in this furnace.

SPECIAL TESTING APPARATUS

Volumeter: The volumeter shown in figure five is a displacement volumeter using mercury as the liquid which is displaced. To take the volume of a test piece the mercury is allowed to fill the cast iron reservoir A to a line B on the glass tube above the reservoir. The reading of the mercury level in the burette C is made, then the mercury is drawn out of the reservoir by water-suction until it is below the flange joint. The top part of A is removed by loosening the nuts, the test piece inserted into the reservoir, and the cover replaced. The water-suction is turned off and the mercury allowed to flow into the reservoir until it reaches B when a second mercury level is read. The difference between the two readings give the volume of the test piece.

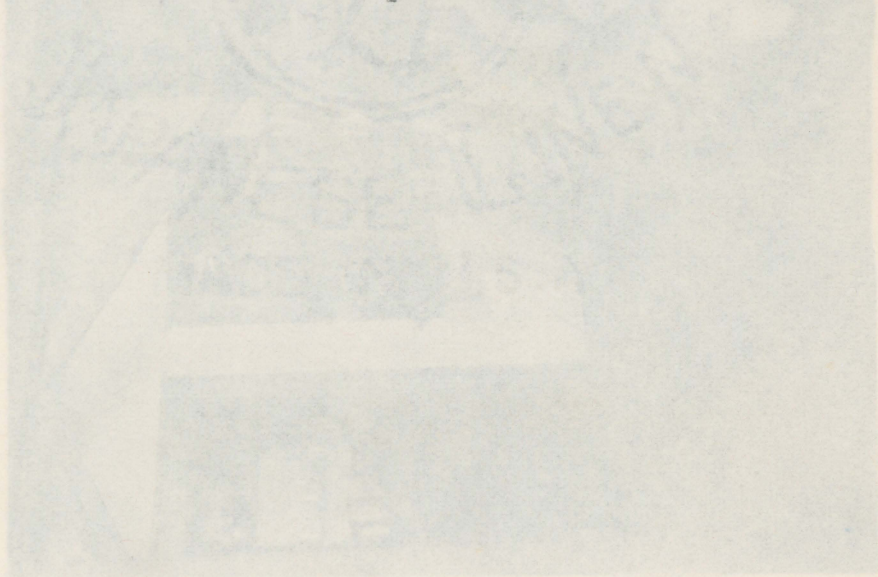


Figure 5. Dry and Wet Test Piece

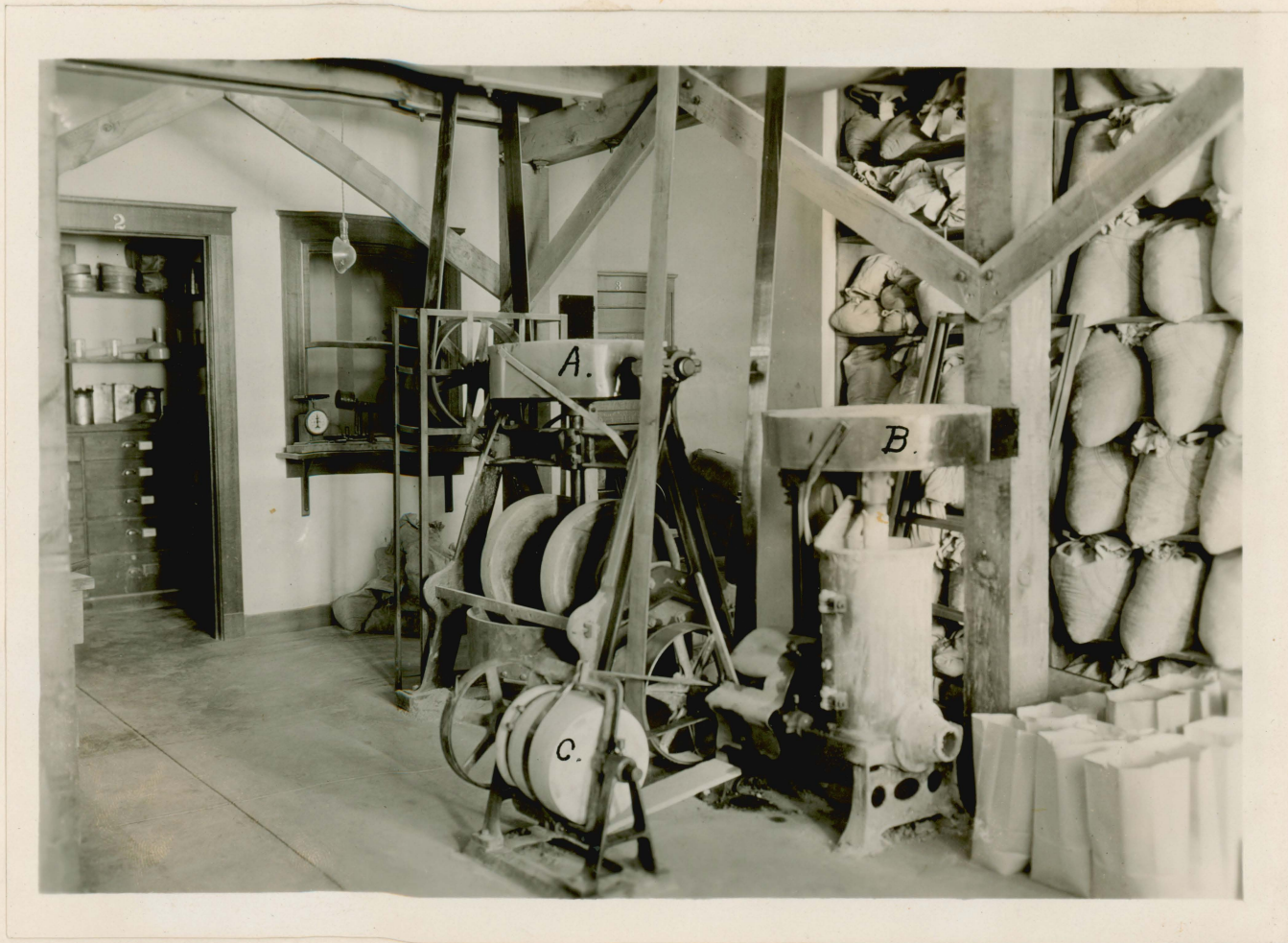


Fig. 1. A. Dry and Wet Pan, B. Pug Mill, C. Ball Mill



Fig. 2 Auger Machine.

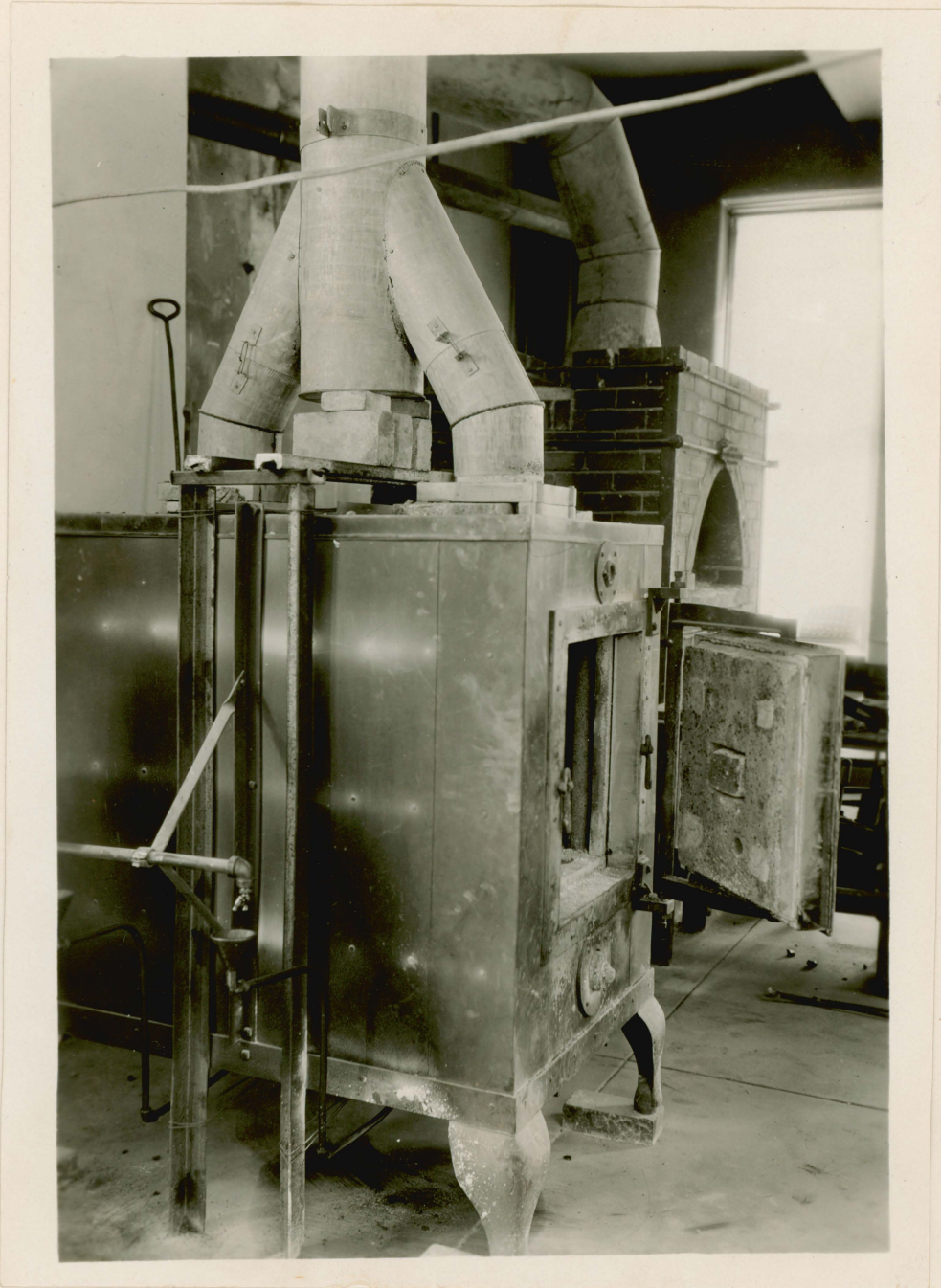


Fig. 3 Pottery Kiln.

Fig. 4 Fusion Furnace.

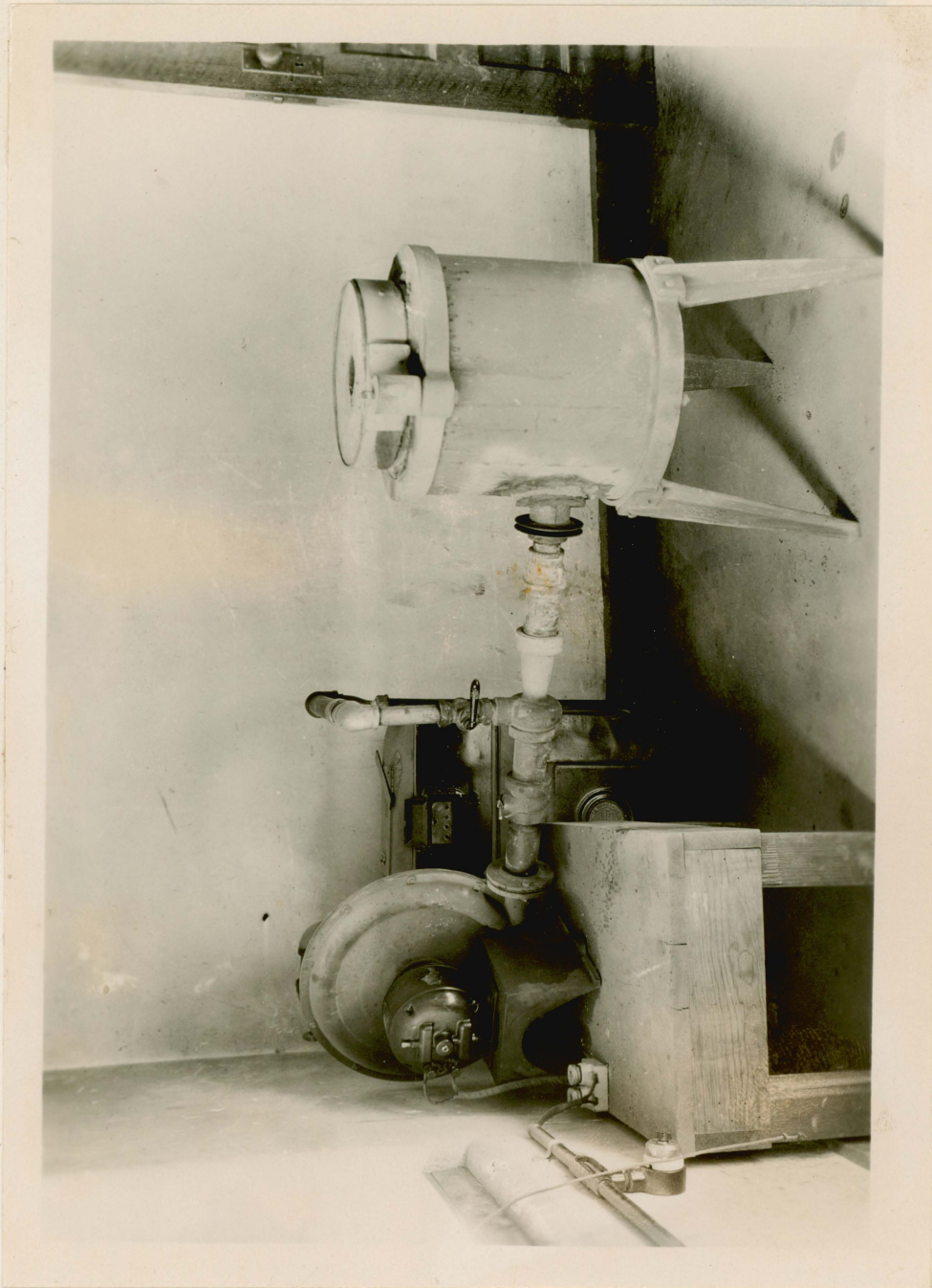


Fig.4 Fusion Furnace.

METHODS EMPLOYED IN TESTING CLAYS

The methods which were used in testing the clays

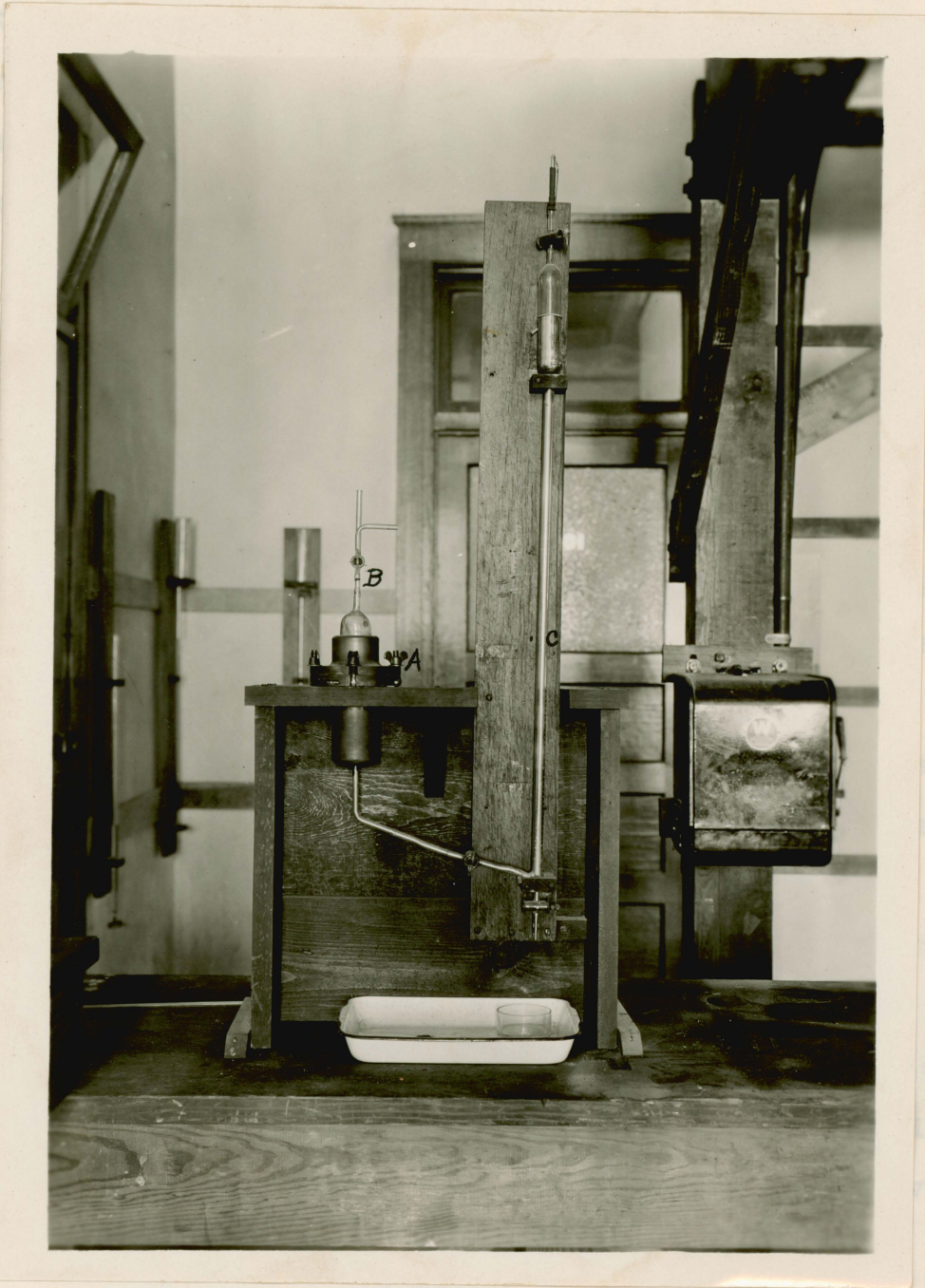


Fig. 5 Volumeter.

About 2500 grams of ground clay are taken and enough water added to develop maximum plasticity. The condition of maximum plasticity is determined by the clay being just dry enough so that a clean dry spatula can be drawn through the mass

METHODS EMPLOYED IN TESTING CLAYS

The methods which were used in testing the clays are those employed in the Department of Ceramic Engineering, University of Illinois. The tests are based on the procedures endorsed by the Committee on Standards of the American Ceramic Society.

The tests which were performed on the clays were those which would determine whether or not they could be used for white-ware, porcelain, or refractories; but if the clays were found to have uses other than these it is so stated.

The determinations which have been made are air-shrinkage, fire-shrinkage, fusion point, point of incipient vitrification, point of vitrification, color burned, plasticity, and cohesion.

All of the samples are air dried before they are tested. After becoming thoroughly dry, about ten pounds of each clay is put through a jaw crusher which reduces it to one-fourth inch mesh. The crushed clay is then reduced to thirty mesh or smaller in a ball mill, after which it is ready for testing. No attempt is made to remove any of the original impurities, but great care is taken to prevent contaminating the clay in any way. Thus these tests are representative of the clay as it comes from the mine.

About 2500 grams of ground clay are taken and enough water added to develop maximum plasticity. The condition of maximum plasticity is determined by the clay being just dry enough so that a clean dry spatula can be drawn through the mass

without the clay adhering to it.

After it has been moistened to the required plasticity it is wedged and kneaded until a fresh cut with the spatula shows that the mass contains no air bubbles. The clay is then placed in a damp jar and allowed to age twenty four hours.

At the end of this time twenty briquettes 2.5X2.5X10cm. are molded in an oiled brass mold. Eight cones with a triangular base, 7mm. on a side, and ^{an} altitude of 30mm. are also made for the fusion point determination.

The briquettes are dried in air until they no longer feel moist to the touch, after which they are placed in a steam heated dryer, where they remain for at least twenty-four hours. The drying is completed by forty-eight hours in an electric dryer at a temperature of 110°C.

On removal from the electric oven they are placed in desiccators until cool, after which they are weighed, measured, and the volumes taken by a displacement volumeter.

As soon as twenty clays have been made up and the volume, weight, and length taken of each briquette they are placed in the pottery kiln in ten piles of forty briquettes each, every pile containing two briquettes of each clay.

There are to be two briquettes of each clay drawn at temperatures of 950°C., 1010°C., 1050°C., 1090°C., 1170°C., 1210°C., 1250°C., 1130°C., 1290°C., and 1330°C. On the top of each pile of briquettes is placed a plaque of fire clay containing three seger cones, one fusing just below the temperature to which the briquettes are to be burned, one fusing at the

temperature, and the other fusing just above it.

It takes about eight hours to obtain cone 010 or a temperature of 950°C. Just before 950°C. is reached cone 012, which is the next lower cone, will go down, and then very careful watch is kept for cone 010 to fuse. When it does go down the fire brick is removed from the door of the kiln and all the briquettes in the first pile are drawn from the kiln and packed in ground flint to prevent too rapid cooling. This procedure is repeated, a drawing taking place about every hour until cone 10 or a temperature of 1330°C. is reached, when the last pile of briquettes is drawn. The draw trials come rather regularly until the last three temperatures are approached, and then some difficulty is experienced in raising the temperature. The period of firing varies from twenty-eight to thirty six hours. After the briquettes are sufficiently cool they are weighed, measured, the color noted, and the points of incipient vitrification, and vitrification are recorded.

Description: The bed is about 6 feet in thickness and stands almost vertical. The clay is very hard, fine grained, and light gray in color. It contains some carbonaceous material, and is slightly ironstained.

Conclusion: This clay should be suited to the manufacture of stoneware and earthenware soft and dry-pressed brick.

Sample M2.

Location: Same as M1. except 310 feet from mouth of tunnel.

THE LOCATION, DESCRIPTION, AND USE OF THE CLAYS TESTED.

In the following pages, the location, the field description, and the uses to which the tested clays may be put are given in the order in which the samples were collected.

The uses, to which each clay is adapted, were determined from the data obtained in making the physical tests. These data are not included in this report on account of the large amount of space which they would occupy. However, they may be obtained from the Colorado Geological Survey, Boulder, Colorado.

Sample M1.

Location: East of road between Golden and Coal Creek; south of Moffat Railroad at old clay mine at east end of tunnel.

Description: The bed is about 6 feet in thickness and stands almost vertical. The clay is very hard, fine grained, and light gray in color. It contains some carbonaceous material, and is slightly ironstained.

Conclusion: This clay should be suited to the manufacture of stoneware and earthenware soft-mud and dry-pressed brick.

Sample M2.

Location: Same as M1. except 310 feet from mouth of tunnel.

Sample M2. Description: The bed is about 5 feet thick and stands almost vertical. It is a hard fine grained, buff colored clay with conchoidal fracture. It is ironstained and sandy in places.

Conclusions: This clay should make good earthenware and soft-mud and dry-pressed bricks.

Location: Same as M1. Taken from shoot at east end of tunnel.

Sample M3. Description: This is a light gray, hard, fine grained clay with an uneven fracture.

Conclusions: This clay might be used for dry-pressed bricks, but trouble would be experienced in drying as the clay is very plastic.

Sample M4.

Location: On Boulder-Lyons road two miles north of Boulder where road crosses Dakota hogback.

Description: The clay occurs in a bed eight inches thick, and is the top bed in the clay series. It is a very hard, medium grained, dark bluish gray, shaley clay with uneven fracture.

Conclusions: This clay would make good light gray soft-mud and dry-pressed brick, but the small amount available prohibits its use for brick.

Sample M5.

Location: Same as M7, but it is from south end of

Sample M5.

Location: Same as M4. but it is the bottom bed of the clay series.

Description: This is a hard, medium grained, dark gray shale breaking into irregular pieces.

Conclusions: This clay will make soft-mud and dry-pressed bricks but trouble may be experienced in drying as the dry shrinkage is almost ten per cent.

Sample M6.

Location: Just east of spillway of dam at Arkins.

Description: It is a light greenish and yellow, hard, coarse grained clay with irregular fracture.

Conclusions: This clay will make good soft-mud and dry-pressed brick.

Sample M7.

Location: On east side of road between Golden and Morrison about five miles south of Golden. Sample is from south end of first excavation east of Dakota ridge.

Description: Bed is from 6 to 8 feet thick and stands vertical. The clay is very hard, fine, and dark brownish gray in color.

Conclusions: This is a white-burning clay of good plasticity which when washed could be used in the manufacture of white-ware and porcelain. It is also a No.1. fire clay.

Sample M8.

Location: Same as M7. but it is from south end of

second excavation east of Dakota ridge.

Description: The bed is about 6 feet thick and stands on edge. The clay is dark gray in color, very hard, fine textured and breaks with a conchoidal fracture.

Conclusions: This clay is white burning and has fine plasticity. It should be a good white-ware, floor-tile, wall-tile, or porcelain clay when washed. It is also a No.1. fire clay.

Sample M9.

Location: Same as M7 but from 4-inch bed in east side of excavation of M8.

Description: It is a dark gray very hard, fine grained clay with a conchoidal fracture.

Conclusions: This is a white-burning clay with good plasticity which when washed may be used for white-ware, wall-tile, floor-tile, and porcelain. This is also a No.1. fire clay.

Sample M10.

Location: From Denver beds about one mile south and west of Golden. M10 was taken from south end of first cut south of cabin.

Description: The beds of clay vary greatly in thickness but the average is about 30 feet. They are easily mined as they stand on edge. It is a light gray, fine grained, medium hard clay with a conchoidal fracture.

Conclusions: This clay will make stoneware clay but it has high air shrinkage.

Sample M11.

Location: Same as M10. but from east side of second cut south of cabin.

Description: The bed is about 20 feet thick and stands vertical. The clay is a light gray in color with tinges of buff. It is fine grained and medium hard, and has a sub-conchoidal fracture.

Conclusions: This clay will make sewer pipe if blended with another clay of lower air shrinkage.

Conclusions: This shale should make dry-pressed and

Sample M12.

Location: Same as M11. but from west side of cut in contact with bed of carbonaceous clay.

Description: Bed is from 15 to 20 feet thick and stands vertical. It is a light gray medium grained medium carbonaceous clay with conchoidal fracture.

Conclusions: This clay has an air shrinkage of 12.35% but it should make good sewer pipe if mixed with a fire clay.

Conclusions: This shale has no uses in the ceramic industries.

Sample M13.

Sample A3. Location: Same as M10. but from cut farthest west from the cabin.

Description: The bed stands vertical and about 10 feet thick. The clay is buff gray, carbonaceous, medium hard, and fine grained, and has a conchoidal fracture.

Conclusions: This clay will make good sewer pipes if mixed with some other clay to reduce the air and fire

shrinkage. color. It breaks with a conchoidal fracture.

Conclusions: This material is worthless on account of its high air shrinkage and cracking.

Location: About 4 miles south of Pikes Peak Ocean to Ocean highway and one-half mile east of Utah boundary line.

Description: Near top of McElmo about 100 feet below Dakota. The bed is 30 feet thick and dips slightly northeast. The shale is gray green in color, medium soft, and medium grained.

In McElmo below a thick dark red bed of sandy shale. Conclusions: This shale should make dry pressed and soft-mud bricks. It is medium soft, medium grained, and a greenish gray in color.

Sample A2. Conclusions: This shale has no economic value.

Location: Same as above but 20 feet lower in the formation.

Description: Bed about 8 feet thick dipping slightly to the northeast. The shale is medium soft, medium grained, and green-gray in color.

Conclusions: This shale has no uses in the ceramic industries. The top of the McElmo. The shale is medium hard, medium soft, and is a greenish gray in color.

Sample A3. Conclusions: Material is worthless on account of cracking.

Location: West of Mack, 630 feet south of D. and R.G.W. R.R., just west of point where Salt Creek meets railroad.

Description: In McElmo below thick dark red bed of sandy shale. The bed from which the sample was taken is 8 feet thick. The shale is hard, medium grained, and gray-

green in color. It breaks with a conchoidal fracture.

Conclusions: This material is worthless on account of its high air shrinkage and cracking.

Sample A4.

Location: West of Mack about 800 feet north and 150 feet above D. and R.G.W. R.R. and about 1100 feet east of railroad bridge over Salt Creek.

Description: In McElmo below a thick dark red bed of sandy shale. The shale bed from which the sample was taken is 12 feet thick. It is medium soft, medium grained, and a greenish gray in color.

Conclusions: This shale has no economic value.

Sample A5.

Location: On road from Fruita to Colorado National Monument; .3 of a mile south from bridge over Grand River and 400 feet south 67° east from the road.

Description: The sample was taken from a bed 7 feet thick near the top of the McElmo. The shale is medium hard, medium soft, and is a greenish gray in color.

Conclusions: Material is worthless on account of cracking badly on drying.

Sample A6.

Location: Location same as above.

Description: This sample was taken from a six-foot bed 20 feet above A5. The shale is medium hard, fine

grained, and a greenish gray in color. It breaks with a conchoidal fracture.

Conclusions: This material has no economic value on account of high air shrinkage and excessive cracking on drying.

Sample A14.

Sample A11.

Location: Salt Wash, lot 15, Sect.1, T.8S.,R.102W.

Description: A six-inch bed of shale below 7 foot bed of coal in the Mesa Verde formation. The shale is very hard, medium grained and a dark gray-brown in color.

Conclusions: This shale may be used for cream colored and light gray soft-mud and dry-pressed brick.

Sample A12.

Location: About 6 miles south of Grand Junction on west side of Gunnison River in Billings Canon about 15 miles from D. and R.G.W. Railroad.

Description: Sample was taken from a 2.5-foot bed in the McElmo. The shale is medium hard, medium textured, and a grayish chocolate in color.

Conclusions: Excessive cracking on drying makes this shale worthless.

Sample A16.

Sample A13.

Location: Same as A12; in Billings Canon 1.2 miles from D. and R.G.W. Railroad.

Description: The sample was taken from a bed in the

McElmo five feet of which was exposed. The shale is hard, fine grained, and medium gray in color.

Conclusions: This shale is of no value due to excessive cracking on drying.

Sample A14.

Location: Same as A12, in Billings Canon 4500 feet from D. and R.G.W. Railroad.

Description: This sample was taken from a three-foot bed in the McElmo. The shale is hard, fine grained, and a medium gray in color.

Conclusions: Excessive cracking on drying makes this material worthless.

Sample A15.

Location: South of Grand Junction on west side of Gunnison River in a little gulch opposite the old dam.

Description: This sample was taken from a 5-foot bed just below a sandy red layer in the McElmo. The shale is hard medium grained and gray-green in color.

Conclusions: This material is worthless on account of its excessive cracking on drying.

Sample A16.

Location: Same as A15.

Description: Sample taken from 18-inch bed two feet below A15. The shale is hard, medium grained, and light chocolate in color. The fracture is conchoidal.

Sample A17.
 Conclusions: This material has no commercial value due to excessive cracking on drying and high air-shrinkage.

Sample A17.

Location: North of Grand Junction; N.W. $\frac{1}{4}$, Sect. 12, T.1S., R.1W., at plant of Grand Junction Clay Products Co.

Description: Sample taken from a 20-foot bank of shale below 18 inches of sandstone in Mancos shale. This shale is fine grained, soft and medium gray in color.

Conclusions: This shale will make soft-mud and dry-pressed bricks.

Sample A18.

Location: Same as A17.

Description: Sample across bank above sandy bed mentioned under A17.

Conclusions: This shale will make soft-mud and dry-pressed bricks.

Sample A19.

Location: North of Grand Junction, N.W. $\frac{1}{4}$, Sect. 7, T.1S., R.1W.

Description: Sample taken across upper half of a 60-foot bank of Mancos shale. The shale is medium soft, fine grained, and a medium gray in color.

Conclusions: This clay will make soft-mud and dry-pressed brick.

Sample A20.

Location: Same as A19.

Description: Sample across lower half of bank mentioned under A19. This shale is very hard, medium grained, and medium gray in color.

Conclusions: This shale will make soft-mud and dry-pressed brick.

Sample A21.

Location: In gulch 390 feet N.80°E. of Glade Park road, six miles south of Grand Junction.

Description: Sample was taken from a 5-foot bed, which dips slightly to the north, near the top of the McElmo formation. The shale is very hard, medium grained, and medium greenish gray in color.

Conclusions: This clay would make a very attractive stiff-mud and dry-pressed brick if burned to cone 6. Burning would be most successful in a tunnel kiln as the total shrinkage will run a little over 16 per cent.

Sample A22.

Location: Same as A21. but one-quarter of a mile from road.

Description: Sample was taken from a 40-foot bed, which dips S.80°W. in the top of the McElmo formation. The shale is very hard, medium grained and light greenish gray in color.

Conclusions: This material is worthless on ac-

count of excessive cracking on drying and swelling during burn. this material worthless.

Sample A23.

Location: On chocolate colored bench on west side of Glade Park road 7 miles south of Grand Junction.

Description: Sample was taken from a 5-foot bed near top of McElmo. A small amount is under a 6 to 8-inch cover. The shale is very hard, very fine, and white in color.

Conclusions: Material is worthless on account of its high shrinkage and cracking on drying. shrinkage.

Sample A24.

Location: About 700 feet northwest of the location of A23. is one mile northwest of Bridgeport.

Description: Sample taken from a 5.5-foot bed near top of McElmo. The shale is very hard, very fine, and white in color. lined, and very light gray in color.

Conclusions: An air shrinkage of 31 per cent and cracking on drying make this material worthless. manufacture of clay products.

Sample A25.

Sample A25 Location: In bank on east side of Glade Park road 8 miles south of Grand Junction.

Description: Same bed as described under A23 and A24. It is about 6 feet thick. The shale is very hard, medium fine, and very light gray-green in color. with purple.

Conclusions: An air shrinkage of 33 per cent on makes this material worthless. on drying.

Sample A26.

Location: On southeast side of the Unweep^a Canyon road 9 miles from Whitewater.

Description: Sample was taken from a 4-foot bed in the McElmo formation. The shale is very hard, medium very grained, and very light gray in color. color.

Conclusion: This material can not be used for high clay products on account of excessive air shrinkage.

Sample A27.

Location: About 2000 feet northeast from point on railroad, which is one mile northwest of Bridgeport.

Description: A 2-foot bed, which dips gently to the northwest, in the McElmo formation. The shale is hard, medium grained, and very light gray in color.

Conclusions: This shale has a total shrinkage of 18 per cent which would prohibit its use in the manufacture of clay products.

Sample A28.

Location: Near top of cliff at east end of highway bridge. Location: Same as A27. one-half mile east of Austin.

Description: Ten feet lower in the formation than A26. The bed is 7 feet thick. The shale is very hard, medium grained and in color a light gray spotted with purple. hard, fine grained, and a very light gray in color.

Conclusions: This clay has no economic value on account of excessive cracking on drying.

Sample A29.

Location: Same as A27 but one-quarter of a mile from the railroad.

Description: This sample was taken from a 3-foot bed in the middle of the McElmo formation. The shale is very hard, fine, and light greenish gray in color.

Conclusions: This material is worthless due to high air shrinkage and excessive cracking on drying.

Sample A30.

Location: Between Grand Junction and Delta; Sect. 14, T.14S., R.98W. 14.2 miles from Delta.

Description: Sample was taken from an 8-foot bed near top of McElmo. The shale is very hard, fine grained, and a light greenish gray in color.

Conclusions: This material is worthless on account of its low plasticity and lack of cohesion.

Sample A32.

Location: Near top of cliff at east end of highway bridge over the Gunnison River one-half mile east of Austin.

Description: Sample was taken from a 7-foot bed near the top of the McElmo formation. The shale is very hard, fine grained, and a very light gray in color.

Conclusions: This shale can not be used for clay products because the total shrinkage is too high.

Sample A37.

Sample A33.

Location: East of Gunnison River between Grand Junction. Location: Same as A32, but 150 feet higher in the formation.

Description: Sample was taken from a 10-inch bed very near top of the McElmo formation. The shale is very hard, medium grained and dirty white to light cream in color.

Conclusions: This clay has no value on account of its excessive air shrinkage.

Sample A34.

Location: In gulch one-half mile N.40°W. from road at rim of Rio Escalante Ca^ynon 14.2 miles from Delta.

Description: This sample was taken from a 10-inch bed above the middle of the McElmo formation. The shale is very hard, medium grained, and very pale green in color.

Conclusions: This material is worthless on account of excessive cracking on drying.

Sample A35.

Location: In branch of No-thoroughfare Ca^ynon on Glade Park road 7.5 miles south of Grand Junction.

Description: Sample was taken from a bed about 5 feet thick near top of McElmo formation. The shale is very hard, very fine, and white in color.

Conclusions: This shale has no economic value on

account of excessive cracking and high air shrinkage. pressed bricks.

Sample A37.

Location: East of Gunnison River between Grand Junction and Delta, Sect.11, T.14S., R.98W., near south boundary of section.

Description: Sample was taken from a 20-foot bed in the McElmo formation. The shale is very hard, medium grained, and pale green in color.

Conclusions: A high air shrinkage prevents the use of this clay in the manufacture of clay products.

Sample A38.

Location: On east side of road to Domingo from Grand Junction near north line of Sect.14, T.14S., R.98W.

Description: This sample was taken from a 2.5-bed in the McElmo formation. The shale is very hard, medium grained, and very pale green in color.

Conclusions: Excessive cracking on drying makes this clay worthless.

Sample A40.

Location: South of Lamar, Sect.34, T.23S.R.,64W., on east bank of Clay Creek.

Description: Sample was taken from a 2-foot bed in Dakota formation. The clay is very hard, medium grained, and dirty brownish gray in color.

Conclusions: This clay is suitable for the manu-

fracture of sewer-pipe, earthenware, soft-mud and dry-pressed bricks.

Conclusion: This material should make dry-pressed

Sample A41.

Location: Same as A40.

Description: Sample taken from 4-foot exposure of bed in Dakota formation. This bed is separated from that of A40 by 4 to 6 inches of sandstone. This clay is very hard, coarse grained, and medium gray in color.

Conclusions: This material should make sewer pipe, earthenware, and soft-mud and dry-pressed bricks.

Conclusions: This clay should make stoneware,

Sample A42. soft-mud and dry-pressed bricks

Location: One half mile east of road from Lamar to Springfield in Sect.8, T.25S., R.46W.

Description: This sample was taken from a 5-foot bed in the Dakota formation. The bed lies about horizontal with an overburden of sandstone 10 feet in thickness. This clay is very hard, fine grained, and medium gray in color.

Conclusions: This clay should make earthenware and soft-mud and dry-pressed bricks.

Conclusions: This clay should make sewer pipe,

Sample A43. stoneware, earthenware, and soft-mud and dry-

pressed bricks. Location: About 1.1 miles north of Caddoa on west side of the road in Sect.1, T.23S., R.50W.

Description: This sample was taken from an 8-foot bed, which lies horizontal, in the Dakota formation. The overburden is composed of about 10 feet of sandstone

and sandy shale. The clay is medium hard, fine grained, and a medium brownish gray in color.

Conclusion: This material should make dry-pressed brick.

Sample A44.

Location: About .9 of a mile north of Caddoa on east side of the road in Sect.1., T.23S., R.50W.

Description: This sample was taken from a 4-foot bed in the Dakota below a massive sandstone. The clay is hard, fine grained, and a light gray in color.

Conclusions: This clay should make stoneware, earthenware, soft-mud and dry-pressed bricks

Sample A46.

Location: On north side of road 2 miles east of Caddoa in Sect.9, T.23S., R.49W.

Description: Sample was taken from a 7-foot bed in the upper Dakota. The overburden is 4 feet of sandy shales and friable sandstones. The clay is very hard, medium grained, and medium to light gray in color.

Conclusions: This clay should make sewer-pipe, drain-tile, stoneware, earthenware, and soft-mud and dry-pressed bricks.

Sample A47.

Location: On west bank of Cottonwood Creek north of bridge in Sect.9, T.27S., R.51W. This location is about

26.6 miles south of Las Animas.

Description: This sample was taken from a bed about 11 feet thick probably about the middle of the Morrison formation. The overburden is very heavy. The clay is soft, medium grained, and light greenish gray in color.

Conclusions: This clay is not suitable for the manufacture of clay product on account of its high air shrinkage.

Sample A48.

Location: On the north side of an old road .5 of a mile north of Tarbox Arroyo and .25 of a mile west of Sect. Purgatoire River in Sect. 10, T.24S., R.52W.

Description: This sample was taken from a 3-foot bed in the upper Dakota. The overburden consists of a few inches of sand near the outcrop but thickens to the north and west.

Conclusions: This clay will make white and light cream dry-pressed brick.

Sample A52.

Sample A49. Location: Same as A51.

Location: About one-quarter of a mile east of road to Higbee in Sect. 25, T.26S., R.54W. under A51. The clay is

Description: Sample was taken from a 3-foot bed in the Morrison. The clay is soft, fine grained, and light grayish green in color.

Conclusions: This clay should make dry-pressed

brick. A53.

Location: On north side of road which runs south

Sample A50. Higbee along the Furgatoire River in Sect. 7, T.27S.,

R.54W. Location: Same as A49.

Description: Sample was taken from a 6-foot bed 12 feet below that of A49. The clay is soft, fine grained, and light greenish gray in color. medium grained, and light

greenish Conclusions: This clay is worthless due to excessive cracking on drying. This clay is worthless due to excessive cracking during drying.

Sample A51.

Sample A54 Location: On east side of road to Higbee in Sect. 11, T.27 S., R.54W. In Las Animas County 450 feet west of

Furgatoire Description: This sample was taken from a 2-foot bed in the Morrison. The clay is medium hard, fine grained, and light greenish gray in color. formation. The clay is me-

diu fine Conclusions: This clay is of no value due to excessive cracking on drying. This clay has no economic value on account of high air shrinkage and excessive cracking dur-

Sample A52.

Location: Same as A51.

Sample A55 Description: This sample was taken from a 2-foot bed 35 feet above the bed mentioned under A51. The clay is hard and coarse grained. It is a light greenish gray in color with streaks of purple through it. taken from a 4-foot

exposure Conclusions: This clay is of no value on account of excessive cracking on drying. dark brownish gray in color.

Conclusions: This clay should make stoneware.

Sample A53. and yellowish white stiff-mud and dry-pressed bricks. Location: On north side of road which runs south west from Higbee along the Purgatoire River in Sect.7, T.27S., R.54W. 153.

Description: Sample was taken from a 2-foot bed in the Morrison. The bed is overlaid by sandstone and red shale. The clay is medium soft, medium grained, and light greenish gray in color. is very hard, very fine, and medium

gray in color. Conclusions: This clay is worthless due to excessive cracking during drying. may be used in the manufacture of stone, earthenware, and stiff-mud and dry pressed

Sample A54.

Location: In Las Animas County 450 feet west of Purgatoire River road 14 miles from Higbee.

Description: This sample was taken from a 4-foot bed near the top of the Morrison formation. The clay is medium fine grained, soft, and light grayish green in color. 4-foot bed Conclusions: This clay has no economic value on account of high air shrinkage and excessive cracking during drying. and a dark gray in color.

Conclusions: This material will make a No.3 fire

Sample A55.

Location: About 800 feet west of railroad 1.1 miles north of Delhi in Sect.35., T.27S., R.59W.

Description: This sample was taken from a 4-foot exposure of a much thicker bed in the Dakota. The clay is very hard, fine grained, and a dark brownish gray in color.

Conclusions: This clay should make stoneware,

earthenware, and yellowish white stiff-mud and dry-pressed bricks.

Sample A56.

Location: About one-half mile west of Delhi rail-

road station on the north side of a little gulch.

Description: Sample was taken from a 5-foot bed

in the Dakota. The clay is very hard, very fine, and medium

gray in color.

Conclusions: This clay may be used in the manu-

facture of stone, earthenware, and stiff-mud and dry pressed bricks.

Sample A57.

Location: One-third mile southwest of Delhi just

across the creek from the pumping station.

Description: This sample was taken from a 3 to 4-

foot bed in the Dakota. The overburden which is absent at

the outcrop increases to the south. The clay is very hard, fine grained, and a dark gray in color.

Conclusions: This material will make a No.3 fire

clay.

Sample A58.

Location: About 70 feet west of tunnel of Engle-

ville Mine at Engleville.

Description: Sample was taken from a 4-foot bed

one mile north of New Mexico boundary line.
 in the Vermejo formation. Bed is capped by a thin bed of
 coal. The clay is hard, fine grained, and dark brownish
 gray in color.

Conclusions: This clay may be used for making dry-
 pressed brick.

Sample A59.

Location: Same as A58.

Description: This sample was taken from a 3.5-
 foot bed just above the coal which caps the bed mentioned
 under A58. The clay is hard, fine grained, and medium gray
 in color.

Conclusions: This clay should make good dry-pres-
 sed brick and earthenware.

Sample A60.

Location: On east side of road to Raton 7 miles
 south of Trinidad.

Description: This sample was taken from a 3-foot
 bed in the Raton formation. This clay is overlain by a bed
 of coal and underlain by a thin bed of sandstone. The clay
 is hard, fine grained, and medium gray in color.

Conclusions: This clay should make good dry-
 pressed brick and earthenware.

Sample A61.

Location: On west side of Raton Pass road about

one mile north of New Mexico boundary line. *ass road about .3*

of a mile Description: This sample was taken from a 2-foot bed in the Raton formation. This bed has about 5 feet of overburden composed of shales and sandstone. The clay is hard, medium grained and dirty brown in color.

Conclusions: This clay should make earthenware and soft-mud and dry-pressed brick.

Sample A62.

Location: Same as A61. *gulch near a small coal*

mine, probably Description: This sample was taken from a 2.5-foot bed which is separated from that mentioned under A61 in by a 4-foot bed of sandstone. The over burden is 18 inches of weathered shale. The clay is medium hard, very fine grained, and dark gray in color. *is suitable for the manu-*

facture of Conclusions: This clay should make good dry-pressed brick.

Sample A66.

Sample A63. *Location: At Little Mary Mine in Sect. 30, T. 333.,*

R. 63W. Location: On Raton Pass road 1.2 miles north of New Mexico boundary line. *is sample was taken from a 4-foot*

bed in the Description: This sample was taken from a 9-foot bed in the Raton formation. The clay is medium hard, medium grained, and brownish gray in color.

Conclusions: This clay may be used for dry-pressed brick. *earthenware and dry-pressed brick.*

Sample A64.

Location: On east side of Raton Pass road about .3 of a mile north of Gallinas.

Description: This sample was taken from a 4-foot bed in the Raton formation. The clay is medium hard, fine grained, and medium brownish gray in color.

Conclusions: This clay may be used for earthenware and dry-pressed bricks.

Sample A65.

Location: West of little gulch near a small coal mine, probably in Sect.30., T.33S., R.63W.

Description: Sample was taken from a 7-foot bed in the Raton formation. The clay is hard, medium grained, and brownish black in color.

Conclusions: This clay is suitable for the manufacture of dry-pressed bricks.

Sample A66.

Location: At Little Mary Mine in Sect.30, T.33S., R.63W.

Description: This sample was taken from a 4-foot bed in the Raton formation. The bed was cut by the air shaft 15 feet below the surface. The clay is medium hard, fine grained, and brownish gray in color.

Conclusions: This clay may be used for the manufacture of earthenware and dry-pressed brick.

Sample A67.

Location: Same as A66.

Description: Sample taken from a 4-foot stratum above a coal bed in the Raton formation. The clay is very hard, fine grained, and dark gray in color.

Conclusions: This clay should make gray-white to pale-buff earthenware and dry-pressed brick.

Sample A68.

Location: On north side of road west of Stonewall and just west of the Dakota ridge.

Description: Sample was taken from an 18-inch bed in the Dakota. The beds stand vertical at this point making them easily accessible. The clay is very hard, fine, and dark gray in color.

Conclusions: This clay should make good dry-pressed and stiff-mud bricks.

Sample A69.

Location: on north side of road below a coal bed 2.5 miles west of Vigil.

Description: The sample was taken from a 3.5-foot bed probably in the Vermejo formation. The clay is very hard, medium grained and medium gray in color. It has a peculiar concretionary structure and breaks with a sub-conchoidal fracture.

Conclusions: This clay should make dry-pressed bricks.

Sample A73.

Sample A70.

Location: On north side of road .7 of a mile east of Vigil in Sect.24, T.33S., R.68W.

Description: This sample was taken from a 2-foot bed in the Raton formation. The clay is very hard, medium grained, and light gray in color.

Conclusions: This clay should make earthenware and dry-pressed and stiff-mud bricks.

Sample A71.

Location: On north side of road 3 miles east of Vigil in Sect.19, T.33S., R.67W.

Description: This sample was taken from a 4.5-foot bed in the Raton formation. The clay is hard, medium grained, and brownish gray in color.

Conclusions: This clay may be used in the manufacture of earthenware and dry-pressed brick.

Sample A72.

Location: On north side of road three miles east of Vigil in Sect.28, T33S., R.67W.

Description: This sample was taken from an 11-foot bed in the Raton formation. The clay is hard, fine grained, and a dark gray and brownish gray in color.

Conclusions: This clay should make dry-pressed bricks.

Sample A73.

Location: On north side of the road 1.4 miles west of Larancito in Sect. 32, T. 33 S., R. 66 W.

Description: This sample was taken from a 5.5-foot bed in the Raton formation just above a bed of coal and 15 feet below a heavy sandstone. The clay is hard, fine grained, and black to black-gray in color.

Conclusions: Earthenware and dry-pressed brick may be made from this clay.

Conclusions: This clay may be used for the manufacture of earthenware and soft-mud and dry-pressed bricks.

Sample A74.

Location: On east side of Creek beside railroad at Broadhead, This is in Sect. 21, T. 30 S., R. 65 W.

Description: This sample was taken from a 3.5-foot bed in the lower Raton. The clay is hard, fine grained, and medium gray in color.

Conclusions: This clay may be used in the manufacture of earthenware and dry-pressed brick.

Sample A75. Conclusions: This clay may be used for dry-pressed brick.

Location: On north side of road. 1.5 miles west of Aguilar in Sect. 33., R. 30 S., R. 65 W.

Sample A76.

Description: This sample was taken from a 4-foot bed in the lower part of the Raton formation. The clay is medium hard, fine grained, and light yellowish gray in color.

Conclusions: This clay may be used in the manufacture of earthenware and dry-pressed brick.

Sample A76.

Location: About 1.4 miles west of Hastings on north side of road in Sec. 22, T.31 S., R. 65 W.

Occurrence: This sample was taken from a 4-foot bed above the first lignitic layer above a heavy sandstone in the Raton. The clay is fine grained, medium hard, and medium gray in color with brown and yellow ironstains.

Conclusions: This clay may be used for the manufacture of earthenware and soft-mud and dry-pressed bricks.

Sample A77.

Location: About .5 of a mile west of Berwin in Sec.36, T.31 S.,R. 65 W.

Occurrence: This sample was taken from a 5-foot bed in the Raton formation. The best material seems to be at the bottom of the bed. The clay is fine grained, hard, and medium brownish gray in color.

Conclusions: This clay may be used for dry-pressed bricks.

Sample A78.

Location: About 1 mile east of Ideal near top of bank where stream and road pass under railroad.

Occurrence: This sample was taken from a 6-foot bed of clay in the Vermejo. The clay is fine grained, very hard, and black in color.

Conclusions: This clay will make white-ware and

Conclusions: This clay should make earthenware and soft-mud and dry-pressed brick.

Sample A81.

Sample A79. Location: Same as A80.

Location: About .2 of a mile south of road to the Pueblo, 1.5 miles east of Silver Cliff.

Occurrence: This sample was taken from weathered felsite of unknown thickness and extent. Stained material on mine dumps in this district shows that the felsite is very extensive but very impure in every place where it has been brought to the surface. The clay is medium grained, hard, and white in color, containing many black specks.

Conclusions: This clay should make white dry-pressed brick if burned above cone 05. This clay might be used for white ware if it could be purified by washing. fine grained, very hard, and medium gray in color.

Sample A80. Conclusions: This is a No. 3 fire clay.

Location: On south side of Rattlesnake Hill at a prospect on north side of gulch, 8.9 miles southeast of Silver Cliff. Location: One and one-half miles north of Pen-

rose on the Occurrence: This sample was taken from a vein 5 feet wide which dips S.53° E. at an angle of 42°. The wall rock is felsite. The larger part of the vein material is pink, but white layers up to 18 inches occur. This sample is that of the snow white material which is fine grained and medium soft. fine grained, very hard, and dark gray in color.

Conclusions: This clay will make white-ware and

wall tile.

Location: In gulch on east side of angling

Sample A81. 35, T.25 S., R.63 W.

Location: Same as A80. was taken from a 4.5-

foot bed in Occurrence: Same as A80. The clay is soft, fine grained, and light pink in color. The base of the bed is

sandy and Conclusions: Material is worthless on account of excessive cracking. medium gray in color.

Conclusions: This clay may be used for stone-

Sample A82. pipe, and stiff-mud and dry-pressed brick.

Location: Two hundred feet north of Skyline Pavilion on Skyline Drive, northwest of Canon City.

Occurrence: This sample was taken from a 7-foot bed in the upper Dakota. The bed has several sandy partings and is cut by many veins of limonite. The clay is fine grained, very hard, and medium gray in color. is in a basin 300

feet wide. Conclusions: This is a No.3 fire clay. fine textured, and very dark gray in color.

Sample A83. Conclusions: This clay is mined for a fire clay

and used in Location: One and one-half miles north of Penrose on the old Florence and Cripple Creek Railroad grade.

The sample was taken from the highest tunnel on the east side of the creek. and dry-pressed brick.

Occurrence: This sample was taken from a 7-foot bed in the upper Dakota. The beds dip 20° S.5 E. The clay is medium grained, very hard, and dark gray in color. north of

Conclusions: This is a No.3 fire clay.

Sample A84.

Location: In gulch on east side of angling road in Sec.35,T.25 S.,R.63 W.

Occurrence: This sample was taken from a 4.5-foot bed in the Dakota. The clay contains a 6-inch sandy stratum 18 inches from the top. The base of the bed is sandy and grades into sandstone. The clay is medium grained, very hard, and medium gray in color.

Conclusions: This clay may be used for stoneware, sewer pipe, and stiff-mud and dry-pressed brick.

Sample A85.

Location: Capers Spur in Sec.31,T.24 S.,R.65 W.

Occurrence: Sample was taken across the face of a 25-foot bed in the Dakota. The deposit is in a basin 300 feet wide of unknown length. The clay is very hard, fine textured, and very dark gray in color.

Conclusions: This clay is mined for a fire clay and used in the manufacture of fire brick, but tests show that it fuses below cone 27 which is the minimum fusion point of fire clays. This clay will make stoneware, sewer pipe, and stiff-mud and dry-pressed brick.

Sample A86.

Location: About 1 mile east and a little north of

Location: Same as A87.

Caper's Spur on south side of arroyo, beside an old tunnel.

Occurrence: This sample was taken from a 15-foot bed in the Dakota. A 2-inch bed of sandstone occurs 7.5 feet above the base of the clay bed, and another bed of sandstone 10 inches thick occurs 10.5 feet above the base. The clay is medium grained, very hard, and dark gray to brownish gray in color.

Conclusions: This clay should make stoneware, sewer pipe, stiff-mud and dry-pressed bricks.

Sample A87.

Location: At mouth of old tunnel in Black Canyon about one mile from the south west entrance to the Garden of the Gods.

Occurrence: Sample was taken from a 2-foot bed of clay in rocks of Carboniferous age. The clay is overlain by a heavy sandstone and underlain by 9 inches of sandstone. The clay is fine grained, medium hard, and black in color. It contains gypsum and pyrite in noticeable amounts.

Conclusions: This clay has been used by the Van Briggles Tile and Pottery Company in the manufacture of art pottery. Tests show that it is suitable for the manufacture of stoneware, sewer pipe, and dry-pressed brick.

Sample A88.

Location: Same as A87.

Occurrence: Sample was taken from a 3-foot bed of clay which underlies the 9-inch bed of sandstone mentioned under A87. The clay is fine grained, medium hard, and black in color.

Conclusions: This clay will make stoneware, sewer pipe, and dry-pressed bricks.

Sample A91.

Sample A89.

Location: South of Calhan in Sec.11, T.12 S., R.62 W.

Occurrence: This sample was taken from the upper 6 feet of a 30-foot bed in the Dawson. The clay is overlain by a friable coarse-grained sandstone from 15 to 20 feet in thickness. The clay is medium grained, hard, and grayish white in color.

Conclusions: This clay is being used by the Standard Fire Brick Company of Pueblo, in the manufacture of fire brick. Tests show that it is a No.3 fire clay.

Sample A90.

Location: Same as A89.

Occurrence: Sample was taken from the 3-foot bed which underlies the 6-foot bed mentioned under A89. The clay is medium grained, hard and yellow and grayish white in color.

Conclusions: This clay will make a good No.3 fire clay.

Sample A93.

Conclusions: This clay is mined along with A89 as fire clay. Tests show that it is not a fire clay but that it may be used for earthenware and dry-pressed brick clay.

Location: Southeast of Calhan in Sec.18, T.12 S., R.61 W. Sample was taken about .3 of a mile west of eastern boundary of section.

Occurrence: Sample was taken from a 5-foot bed of clay below a somewhat-forming sandstone in the Dawson.

Sample A91.

The clay is coarse grained, hard, and variegated yellow, pink, and grayish white in color.

Location: South of Calhan, in Sec.18, T.12 S., R.61 W. Clay outcrops on north side of a little wash 0.3 of a mile from southern boundary of the section.

Conclusions: This clay may be used for stoneware, sewer pipe, and dry-pressed and stiff-mud bricks.

Occurrence: This sample was taken from a 4-foot bed of clay in the Dawson. The overburden consists of 3 to 4 feet of soil. The clay is coarse, hard, and very light gray.

Location: About .3 of a mile west of Denver-Colo. Springs road 3.3 miles north of Larkspur.

Conclusions: This clay will make a No.2 fire clay.

Occurrence: Sample was taken from a 4-foot bed in the Dawson below a thin bed of soft sandstone. There is a bed of very sandy clay above the sandstone. The clay is coarse grained, medium soft, and a light gray in color.

Sample A92.

Location: About 4 miles east of Calhan in Sec. 32, T.11 S., R.61 W.

Conclusions: This clay should make stoneware, sewer pipe, and dry-pressed bricks.

Occurrence: Sample was taken from a 10-foot bed in the Dawson. The beds are horizontal and have too much overburden to be mined by open pit. The clay is very fine and very hard. In color it is a grayish white mottled with purplish pink.

Location: Stone City, 600 feet north of the railroad at the mine of the Pueblo Clay Products Company.

Occurrence: Sample was taken from 6- to 8-foot bed in the Dakota. This clay occurs down the dip from the

Conclusions: This clay will make a good No.2 fire clay.

Sample A93. is a fine grained, hard, dark gray clay with a

Location: Southeast of Calhan in Sec.18,T.12 S.,R.61 W. Sample was taken about .3 of a mile west of eastern boundary of section.

Occurrence: Sample was taken from a 5-foot bed of clay below a monument-forming sandstone in the Dawson. The clay is coarse grained, hard, and variegated yellow, pink, and grayish white in color.

Conclusions: This clay may be used for stoneware, sewer pipe, and dry-pressed and stiff-mud bricks.

Sample A95. white ware, and refractory ware. It is a very

Location: About .3 of a mile west of Denver-Colorado Springs road 3.3 miles north of Larkspur.

Occurrence: Sample was taken from a 4-foot bed in the Dawson below a thin bed of soft sandstone. There is a bed of very sandy clay above the sandstone. The clay is coarse grained, medium soft, and a light gray in color.

Conclusions: This clay should make stoneware, sewer pipe, and dry-pressed bricks.

Conclusions: This clay will make red stiff-mud

Sample A96. red brick.

Location: Stone City, 600 feet north of the railroad at the mines of the Pueblo Clay Products Company.

Occurrence: Sample was taken from 6- to 8-foot bed in the Dakota. This clay occurs down the dip from the

tunnel. It is a fine grained, hard, dark gray clay with a conchoidal fracture.

Conclusions: This clay is a No.3 fire clay.

Sample A97.

Location: Same as A96.

Occurrence: Same as A96 except that it occurs up the dip from the tunnel. The clay is fine grained, very hard, and a light gray in color.

Conclusions: This clay is white-burning and non-plastic. After washing it may be used in the manufacture of porcelain, white ware, and refractory ware. It is a very good No.2 fire clay.

Sample A98.

Location: About .3 of a mile southwest of Stone City.

Occurrence: Sample was taken from a 40-foot bed in the Benton shale. The clay is medium grained, soft, and gray-cream in color. It contains gypsum.

Conclusions: This clay will make red stiff-mud and dry-pressed brick.

Sample A99.

Location: About .3 of a mile south of Fire Clay Spur on Moffat Railroad.

Occurrence: Sample was taken from a 4- to 20-foot bed in the Dakota. The clay is fine grained, hard, and brownish gray in color.

Conclusions: This clay is a plastic white-burning clay, which may be used, after washing, in the manufacture of white ware and porcelain. This clay is also a No.1 fire clay having a fusion point above cone 33.

Sample A100.

Location: At Fire Clay Spur west of railroad in the mine of C.F.Wilson.

Occurrence: Sample was taken from a bed in the Dakota which dips N.75° E. at an angle of approximately 75°. The bed varies greatly in thickness, but probably averages about 14 feet. The clay is fine grained, very hard, and dark gray and grayish brown in color.

Conclusions: This clay is a very good No.2 fire clay. With careful washing this clay could probably be used in the manufacture of white ware and porcelain.

Date Due

Date Due	
JAN 8 1925	
Ag 23 '40	
OCT 16 1945	
MAY 25 1950	
MAY 7 1950	
AUG 27 1954	
NOV 25 '60	
ES FEB 9 '76	
ES APR 1 '76	

378.788B } Murray, A. N.

M961a Some white-
ware + refractory clays

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JAN 8 1925

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