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Some Kentucky clays, including kaolinic, plastic and fire clays: clays in several parts of Kentucky, with some account of sands, marls and limestones

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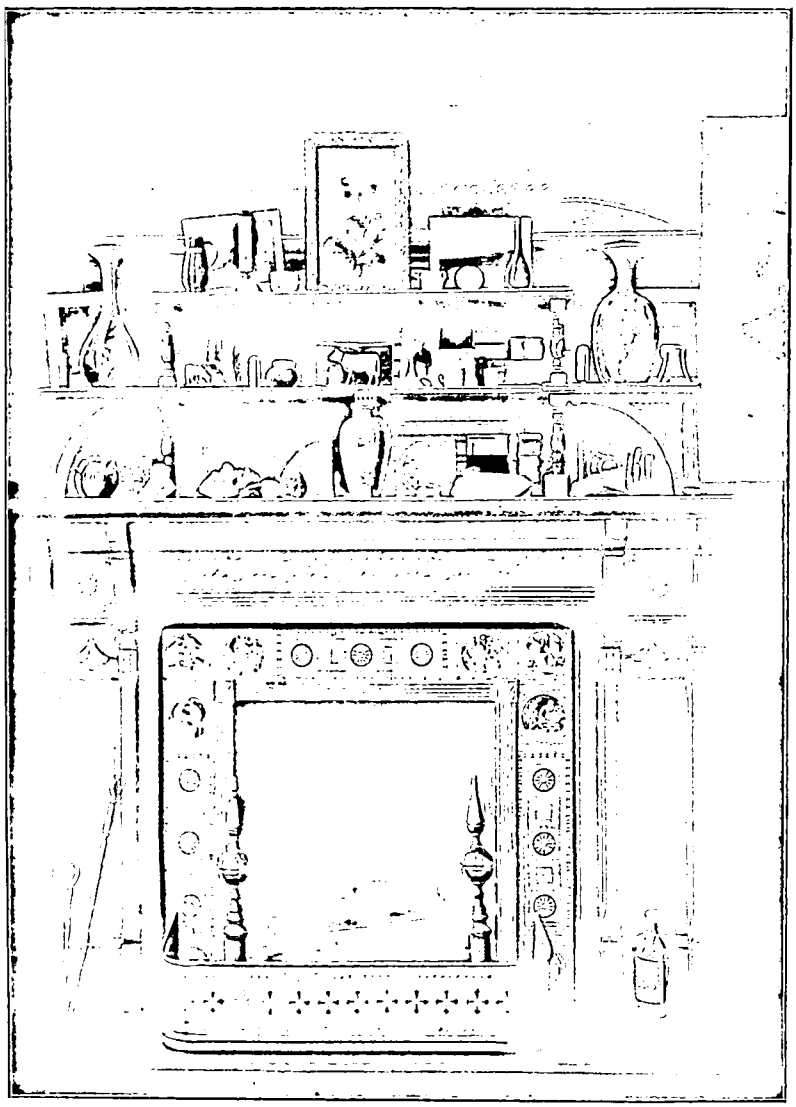

MANTEL DECORATED WITH ART WARES MADE FROM KENTUCKY CLAYS.

Kentucky Geological Survey

CHARLES J. NORWOOD, Director.

BULLETIN NO. 6.

CLAYS IN SEVERAL PARTS OF KENTUCKY,

WITH

SOME ACCOUNT OF SANDS, MARLS AND LIMESTONES.

I. Kaolins and Plastic Clays on the Eastern Rim of the Western Coalfield; Notes on Clays in the Western Lead, Zinc and Spar District (F. J. Fohs); Clays and Sands of Jackson's Purchase; Clays in the Red River Valley,
By JAMES H. GARDNER.

II. Clays of Silurian, Devonian, Waverly and Irvine Formations.
By AUG. F. FOERSTE.

III. Analyses of Miscellaneous Kentucky Clays.

OFFICE OF THE SURVEY: LEXINGTON, KY.

1905.

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1905

CONTENTS.

LIST OF LOCALITIES.

PLATES.

LETTER OF TRANSMITTAL.

His Excellency, J. C. W. BECKHAM,
Governor of Kentucky.

SIR: I have the honor to present for publication a bulletin on clays, with some account of sands, marls and limestones, in several parts of the State. The bulletin is preliminary in character and is offered now simply in order to meet the urgent calls for all information concerning our clays that is at present available. A more comprehensive report, in which not only the geology and distribution of our clays, but also their technological values, will be given, will follow in due course. Data for such a bulletin are being gathered as rapidly as circumstances will permit. Among the clays upon which more field work is required are some of those associated with the coals and Conglomerate Measures of the Eastern Coalfield; those in other Lower Carboniferous regions than are included in this bulletin; those on the western rim of the Ordovician (Lower Silurian), and in parts of the Western Coalfield; while those of the Jackson's Purchase region are to be studied in greater detail. It is believed that another year of field work will yield results sufficient to develop the lines along which technological work may be most profitably carried. Naturally, frequent references are made in this bulletin to materials fit for the manufacture of Portland and other cements. A bulletin especially devoted to cement materials will be issued later on.

Very respectfully,
C. J. NORWOOD,
State Geologist.

October 1, 1905.

LETTER OF SUBMITTAL.

PROFESSOR CHARLES J. NORWOOD,

Director, Kentucky Geological Survey.

SIR: I have the honor to submit herewith a preliminary report on various clay deposits of the State examined during the seasons of 1904 and 1905, including the kaolin and plastic clays of Hardin and Hart counties and portions of Edmonson, Larue, Taylor and Grayson counties, together with miscellaneous deposits in other counties of the State, including Jackson's Purchase in the West and Red River Valley in the East. In doing so, I wish to express my indebtedness to those residing in the various districts of my work who offered me so many facilities and treated me so courteously. They are too numerous for individual mention.

Accompanying the report is an account of the clay deposits of Livingston and Crittenden counties, by Mr. F. Julius Fohs, furnished for use in this bulletin in advance of his forthcoming report on the lead, zinc and spar deposits of the Western Kentucky district.

Very respectfully,

JAMES H. GARDNER,

Assistant Geologist.

October 1, 1905.

PART I.

1. The Kaolins and Plastic Clays on the Eastern Rim of the Western Coalfield, by J. H. Gardner

2. Clays in the Red River Valley, by J. H. Gardner.

3. Clays and Sands of Jackson's Purchase, by J. H. Gardner.

4. Some Clays in the Western Lead, Zinc and Spar District, by F. Julius Fohs.

CHAPTER I.

The Kaolin Deposits Adjacent to the Eastern Rim of the Western Coalfield, with Notes on Other Clays in that Region.

This region includes Hardin, Hart, Larue, Taylor, Edmonson, and Grayson counties. In all the counties named, except Grayson and Hardin (which have not been fully proved), deposits of a fine white clay, to which, on account of its composition and general character, the name kaolin is applied, are known to occur. Work was undertaken in the region with especial reference to the kaolin deposits, but was extended so as to include other clays of importance.

Geologlcal Distribution of the Clays.

The clays are found in the various divisions of the Lower Carboniferous formation, as represented in this territory, but principally in the upper ones.

In Hardin county, the clays around West Point lie within the Waverly belt, but they appear to be much younger geologically, doubtless representing river deposits. The clay, or white silicious soil, is found underlying the level area extending into Jefferson county. This area is an old terrace of the Ohio river, the latter having cut its northern bank and left an area of alluvial material wider and wider on the south. The other clays of the county are of the plastic variety, and are situated between the St. Louis formation and the Big Clifty Sandstone of the Chester Group.

In Hart county, the clays of the western portion are also found between the St. Louis limestone and the Big Clifty Sand-

stone. In the central and eastern portions, however, many of the deposits are situated at the base of the Conglomerate Sandstone of the Coal Measures (representing the Pottsville of Pennsylvania). Over the latter area of the county, there is a marked unconformity at the base of the Upper Carboniferous (or coal-bearing series, including the Conglomerate). The Conglomerate is here, at some places if not at many, brought down almost bodily on to the St. Louis. Beneath an important exposure of kaolin at one point in this area, there is a thin seam of coal underlaid by "fire-clay," which, with possibly a few feet of limestone, is the only representative of the Chester Group. Immediately above the deposit, with a sharp line of demarcation, is the Conglomerate. Only a few feet below, according to barometric measurement, the St. Louis occurs.

In Edmonson county, the Chester Group is well represented, and in it occur the two important clay horizons of the county. One is at the top, between the highest stratum of limestone and the Conglomerate Sandstone; the other is lower down, near the top of the Big Clifty Sandstone. Possibly further work in that county will reveal deposits along the area of contact between the St. Louis Limestone and the Big Clifty Sandstone.

Southeastwardly from Hodgenville, in the region traversed by the Buffalo and Campbellsville road, adjacent to the boundary between Larue and Taylor counties, lying partly in each county, but chiefly in Larue, is an area of twelve or sixteen square miles in which deposits of kaolin have been found at widely separated points. For present convenience, this field has been called the Larue-Taylor clay field. The clay occurs at a level below the base of the Conglomerate Sandstone.

In Grayson county, those deposits that were examined are associated with a stratum of limestone at the top of the Big Clifty Sandstone. No kaolin was observed in the county, but it should be said that examinations of the county have not been completed.

Scope of the Investigations.

The investigations of the deposits were made for the purpose of determining, as nearly as possible, the nature of their occurrence and their extent, and, so well as may be done without

technical and commercial tests, their qualities and applicability; also, for the purpose of ascertaining their relations to the different geological formations, and for collecting such data as might prove valuable in shedding light on their origin. In the course of the field work, samples were collected in such way as to be representative of each deposit as a whole.

The results show that unquestionably valuable clay deposits occur along the eastern margin of the Western Coalfield, and sufficient has been determined to justify the expectation that as the examinations are carried to the west, around the southern margin, other promising deposits may be found.

Prospecting for the Clays.

At numerous places in the territory under consideration, especially in Hart county, the clay deposits have been exposed by shafts or pits sunk to depths ranging from two to twenty feet. This gives the best exposure, enabling one not only to determine the thickness with accuracy, but to ascertain the variation in the character of the clay vertically. At other places the clay may be seen to advantage where surface water has cut gullies through the deposits. This gives exposures on the sides of the cuts and shows, as well, the comparative thickness of the deposit. Great care must be taken at such an exposure, however, in collecting a sample, to see that it shall be an average of the bed and free from impurities washed in by rains.

The presence of clay is often detected by the appearance of the soil covering, or by the character of the vegetation growing thereon. In such case, a pit or a boring is an absolute necessity in order to determine the character and quantity of the deposit.

Varieties of the Clay.

The clays of these counties may, for present purposes, be classified as of three varieties, namely, Kaolins, Plastic Clays, and so-called Fire Clays.

The term kaolin was originally applied to those white clays which result from the decomposition of feldspar. For this reason it is a question whether or not the term should be applied to the white clays of this territory, which undoubtedly

are not residues from decomposed igneous rocks. Since, however, the clays have both the physical and chemical nature of kaolin proper, the term is applied to them in this report. They resemble typical kaolin in being white, grayish-white, or pale yellow; in having an unctuous or greasy feel; in adhering strongly to the tongue, due to porosity; in breaking with a conchoidal fracture; in turning blue when heated and moistened with cobalt solution; and, principally, in analysis.

Following is an analysis of kaolin which occurs on the Philip Moss place, in the Bonnieville region, in Hart county. Sample is of unwashed clay, and was analyzed by Dr. A. M. Peter, chemist for the Kentucky Geological Survey:

	Per cent.
Moisture	2.39
Ignition (combined water)	12.68
Silica	48.09
Alumina	34.66
Ferric oxide	0.78
Lime	0.27
Magnesia	0.23
Potash	0.74
Soda	0.30
Titanic oxide	0.25
	100.39

The following analysis of a typical, high class kaolin from Japan, copied from "Tables of Analyses of Clays," compiled by Alfred Crossley, is given for comparison:

	Per cent.
Water and loss	13.64
Silica	47.74
Alumina	36.66
Ferric oxide	0.42
Lime	0.99
Magnesia	....
Alkalies	0.45
	99.90

The following analysis, also for comparison, and copied from Crossley's Tables, is that of a kaolin from Jacksonville, Ala.:

	Per cent.
Water and loss	13.38
Silica	44.60
Alumina	38.91
Ferric oxide	0.78
Lime	....
Magnesia	....
Alkalies	1.03
Undecomposed mineral	0.90
	99.60

The following analysis of washed kaolin is copied from Dr. Heinrich Ries's report on "The Clay Deposits and Clay Industry in North Carolina." The clay is mined near Webster, N. C., by the Harris Clay Company:

	Per cent.
Moisture	0.35
Water (loss on ignition)	8.98
Silica	45.70
Alumina	40.61
Ferric oxide	1.39
Lime	0.45
Magnesia	0.09
Alkalies	2.82
	100.39
Free sand	3.19

Plastic clays are those which are especially fat or plastic. Such clays contain more or less impurities and often show quite brilliant shades of gray, yellow, brown, drab and red. In this class is included the ordinary red clay which results from the decay of limestones, and which is often used for the manufacture of common red brick.

The fire-clays form a class of dark, refractory clays, which possess little plasticity. This term is a very general one, however, often improperly applied, and it is not to be understood that every clay referred to as "fire-clay" is valuable for fire-proof qualities. When properly used, the term applies to a refractory clay from which fire-proof material may be made. But in common usage the term is often applied to clays that are in reality not sufficiently refractory to make fire-brick, the

term being applied simply because they resemble fire-clay and are more refractory than the ordinary plastic clays. An example of the common misuse of the term is its application to the under-clays of coal seams, without regard to whether they are refractory or not; originating, perhaps, in the fact that often such clays are true fire-clays, and that some of the best fire-clays known are obtained from beneath coal beds. A similar looking clay is not infrequently found beneath deposits of kaolin or of plastic clays in the region covered by this chapter.

It will be noted that the above clays contain more or less impurities, and it may be said that kaolin is never found in a strictly pure state. Kaolinite is known as the clay substance, while all foreign minerals are regarded as impurities. Kaolinite is the basis of all clays, and is the hydrated silicate of alumina, having the formula Al_2O_3, $2SiO_2$, $2H_2O$. Or in the proportion of Silica (SiO^2), 46.3 per cent.; Alumina (Al_2O_3), 39.8 per cent; water (H_2O), 13.9 per cent.

Origin of the Kaolin Deposits.

Clays, according to their mode of origin, are classed as Residual and Sedimentary. Residual clays are those which are found at the place where formed or in the immediate locality.* Sedimentary clays are those which were deposited as a sediment on the bottom of a sea, river, or ocean, the clayey particles having been washed in from the eroded land areas. Just what the origin of kaolin beds in this territory may have been is an unsettled question, but there is weighty evidence in favor of sedimentation.

Upon close examination, some of the deposits of white clay in Hart county proved to be fossiliferous. Specimens of a *Zaphrentis*, of *Pentremites pyriformis*, crinoid columns, and of a small bryozoan (the frond of an Archimedes), were found incorporated deep down in a freshly exposed portion of a bed in such a manner as could not have been brought about by the fossils having been washed in from the surface. It necessarily follows, therefore, that these included fossils must either ante-

* They are residues of earlier formed deposits that have been disintegrated by decay or broken down by erosion, by frosts, etc. The red clays that constitute such a marked feature of areas underlaid by the St. Louis and Ste. Genevieve limestones in Southwestern Kentucky, which have been derived from those limestones, are good examples of residual clays.—C. J. N.

date the deposits or have an age in common with the clay. If they antedate the deposits, then the clay must be a replacement of a limestone or chert in which the fossils were originally held. If they do not antedate the deposits, then the fossils must be the remains of organisms that lived in the same sea and died at the time the clay was being deposited as a sediment over the bottom. The latter seems to be the most probable explanation.

If the clay is a replacement, there is no reason why the fossils themselves should not have been replaced. While it is true that some of the small ones are partially or entirely replaced, it is only such a replacement as might take place *"pari passu"* with the fossil's decay. The larger fossils, like *Zaphrentis,* are apparently in their solid, original form.

Furthermore, the deposits are laminated; they often show very distinct and well marked layers—distinct in color, in physical nature, and in chemical composition. This is a characteristic that we would expect to find only in a sedimentary deposit.

Another important feature in connection with some of the white clay deposits of Hart county is the fact that they are underlaid by a thin stratum of Chester coal, which itself rests upon a typical under-clay (so-called "fire-clay"). It would seem that the close relation of the clay deposit above with the coal and under-clay below is more in accord with the theory of sedimentation than with that of replacement. After the coal was formed, the clay must have been deposited in the comparatively shallow water which followed a slow submergence. However, such a relation could be brought about by unconformity.

The foregoing facts are merely cited as being in favor of sedimentary origin rather than of replacement. On the other hand, some of the clays by association and resemblance seem very much as if they were the result of replaced chert. The deposits, however, are found outcropping entirely around the hills, as if laid down in regular horizontal layers and afterward exposed by erosion; though it is yet to be determined, definitely, whether they do extend through the hills, or whether they are rim deposits.

Why some of the clays are so much, in appearance and composition, like those resulting from the decay of igneous and

metamorphic rocks is a question of theory that will not be discussed in this report. The writer is of the opinion that the majority of the clays in the district are of marine origin, having been carried probably by rivers from a great distance, first into the prongs of the Lower Carboniferous sea and then quietly deposited as local sediments on the bottom.

Physical Properties of Clay.

Plasticity.—All clays are plastic, but they differ in the degree of plasticity which they possess; hence it is that clays of little plasticity are called "lean," while those which are highly plastic are called "fat." In this report, however, the term "Plastic Clay" simply refers to clays that are so plastic that they can neither be included among the kaolins nor the "fire-clays." The kaolins are lean, while the fire-clays are little plastic until ground to a fine state of division.

Slaking.—When clays are dampened or covered with water, they undergo a breaking up, known as slaking. The rapidity with which the several varieties of clay in the region here discussed slake differs greatly. The purest white clays, when thrown into water, give off bubbles rapidly and, in a few minutes, go down completely into a powder. On the other hand, the plastic clays slowly break up into angular fragments, when small pieces are moistened; while the fire-clays still more slowly slake to minute flakes, or else break down to their component grains.

Absorption.—According to Dr. Heinrich Ries, the absorption of a clay increases with the organic matter, the ferric hydrate, and the porosity. At many places in the territory under discussion, there are small springs which issue beneath the top layer of clay deposits. This is probably due to the fact that iron compounds and organic matter, which have been leached into the upper portion, permit the water to be absorbed until the stage of over-saturation is reached. Kaolin is very porous and adheres to damp substances because of moisture absorption.

Color.—The two chief coloring agents of clay are organic matter and the oxide of iron. Both agents have often played their parts in the coloring of the same deposit, and the plastic clays especially are sometimes colored brilliantly.

Kaolin deposits are often ochreous near the top or bottom, or colored brown with manganese oxide. Some high-grade clays which are white after burning are, in their original state, dark or brown with organic matter. Many clays which are slightly stained with ferrous oxide burn red or yellow, because of the reduction of the iron oxide from the ferrous to the ferric state. As a rule, ferrous oxide colors dark or brown, while the ferric oxide colors red or yellow. Some clays contain certain fluxes, like lime for instance, which mask the color of the iron oxide on burning, by the formation of double compounds.

Impurities in Clay.

Perhaps the most common impurity of clays is silica. Silica occurs in two forms, namely, as free silica, in the form of quartz or sand grains, and in chemical union with alumina, which forms the base of all clays. It is in the free state that silica is often injurious, but in some cases it is necessary to add sand in order to render a clay more refractory, or to lessen the degree of shrinkage. Free silica also lessens the plasticity. Silica or sand in excess causes a clay to expand and crumble when burned.

Another common impurity in clay is iron in the form of ferric and ferrous oxides. Peroxide of iron is often carried into a clay deposit by percolating waters, coloring it various shades of red and yellow. If present in sufficient amount, ochre is formed. Iron is also found in some deposits as iron pyrites, or iron disulphide.

A common constituent of clays is lime. Sometimes it is in the proper proportion to form a marl valuable for the manufacture of Portland cement. On the other hand, the proportion may be too small to be of moment as regards use of the clay for Portland, and yet so large as to injure the clay for other manufactures. If a clay containing carbonate of lime is used in the manufacture of bricks and is not burned to a sufficiently high degree of temperature, the calcium carbonate is broken up into the oxide of calcium ("quicklime") and carbon dioxide. The latter escapes in the form of a gas, but the former, which

is unslaked lime, absorbs water on cooling and is apt to burst the brick by swelling.*

In one or two deposits of this territory, lime is found in the form of the crystalized sulphate (gypsum). Gypsum acts as a flux, but it may also do considerable damage by the formation of sulphuric acid.

Manganese, in the form of oxide, is a common impurity in the surface portion of the deposits. But it is rarely present in sufficient amount to be of detriment to the clay.

Other compounds which are common to clays of all localities are magnesia, potash, soda, phosphoric acid, titanic acid, organic matter, and not infrequently sulphuric anhydride.

All clays contain some impurities, and the use of a clay is determined in large measure by the relative percentages of these impurities.

USES OF CLAY.

Perhaps there is no natural product of the earth put to more varied uses and applied to art in a greater number of forms than clay.

Dr. Heinrich Ries, in his general report on the Clays of the United States East of the Mississippi River,† presents an amplification of the table of uses of clay originally compiled by Mr. R. T. Hill.‡ Mr. Hill's instructive table has done service in a number of reports that have been issued on clay deposits, and it is here presented in its amplified form with some modifications:

1. *Domestic.*—Porcelain, white earthenware, stoneware (granite or ironstone), yellow ware and Rockingham ware for table service and cooking; majolica stoves; polishing brick, bath brick, jugs, crocks, churns, jars, fruit jars, milk pans, fire kindlers, etc.

2. *Structural.*—Brick (common, front, pressed, ornamental, hollow, glazed, adobe, terra cotta), roofing tile, glazed and encaustic tile (flooring, fireplace, etc.), drain tile, paving brick,

* The results of insufficient burning in the case of bricks made from clays running relatively high in calcium carbonate, may be seen in many of the brick structures in Central Kentucky, where clays derived from Trenton (Lexington) or Cincinnatian limestones or calcareous shales have been used.—C. J. N.

†Professional Paper No. 11. U. S. Geological Survey, 1903.

‡Mineral Resources U. S., 1891, p. 475.

chimney flues, chimney pots, doorknobs, fire-proofing, terra cotta lumber, copings, fence posts.

3. *Agricultural.*—Drain tile, soil tile, irrigating tile, soil tempering, barn flooring, etc.

4. *Hygienic.*—Urinals, closet bowls, sinks, wash tubs, bath tubs, pitchers, sewer pipe, ventilating flues, foundation blocks, vitrified bricks, absorbent brick, etc.

5. *Hydraulic.*—Water conduits, reservoir lining, etc.

6. *Decorative and Esthetic.*—Ornamental pottery, terra cotta, majolica, garden furniture, tombstones, ornamental tiling, artists' mouldings, base for retaining pigments, etc.

7. *Refractory Wares.*—Crucibles and other assaying apparatus, gas retorts, fire bricks, glass pots, blocks for tank furnaces, saggers, stove and furnace bricks, blocks for fire boxes, tuyeres, pottery kilns, cupola bricks.

8. *Miscellaneous.*—Food adulterant, paint fillers, paper filling and sizing, electric insulators, pumps, well tubing, fulling cloth, scouring soap, packing for horses' feet, chemical apparatus, condensing worms, ink bottles, ultramarine manufacture, emery wheels, playing marbles, battery cups; pins, stilts and spurs for potters' use; shuttle eyes and thread guides, smoking pipes, lamp stands, umbrella stands, pedestals, water filters and coolers, filter tubes, caster wheels, pump wheels, models, flower pots, garden border edging.

9. *Engineering Works.*—Puddle, Portland cement, railroad ballast, covering for wagon roads (burnt clay).

Clay is also used in making alum, and yellow and red clays are used as paints.

Clays Employed.

As stated by Dr. Ries, "very few of the above materials are made from one grade of clay alone; in fact, probably 90 per cent. of the articles mentioned in the above list are molded of a mixture of at least three clays, and many clays are used for several purposes. The aim of the manufacturer in each case is to get a mixture of the proper plasticity, color-burning qualities, shrinkage, and refractoriness. This is a subject to which much consideration is given in the manufacture of the medium and higher grades of ware, for neglect of these points may cause much loss in burning."

It seems well to present the following quotations from the report of Dr. Ries,* concerning the class of clays employed in the more important kinds of ware mentioned above:

China Clays.—"Porcelain, white earthenware, and granite-ware are made of a mixture of kaolin, ball clay, feldspar, and quartz, all rendered very fine-grained by preliminary washing or grinding. The clays must be of the best quality, burning to a white color at the fusing point of cone 8 (about 2,350 degrees F.). This necessitates the selection of a clay of low ferric-oxide content, preferably under 1 per cent. Good plasticity is also desired, and is supplied by the ball clay. The kaolins and ball clays employed are partly of domestic production and partly imported."

Fire-Clays.—"Fire bricks, crucibles, and similar wares are made from clays whose main requisite is refractoriness, although plasticity is also needed. Consequently mixtures of several different clays must be made for the best results. A clay to be considered refractory should not fuse under 3,000 degrees F. (cone 27)."

Glass Pot Clays.—"The manufacture of glass-pots calls for a clay which is not only refractory, but burns dense at a moderately low temperature, so that it will resist the fluxing action of the molten glass. It must possess good bonding power and burn without warping. Great care is necessary in the selection of the clay and the manufacture of the pot."

Stoneware Clays.—"Stoneware is commonly made of a semi-refractory clay, which burns dense and holds its form well in burning. The clays may often show high plasticity and tensile strength (often 150 to 200 pounds per square inch), and not uncommonly burn buff. This is the type employed in chemical and sanitary apparatus."

Clays for Vitrified Wares of Low Grade.—"Sewer pipe, paving brick, and other vitrified wares of nonrefractory character are made from clays or shales of fine grain, ferruginous composition, and preferably of good plasticity and tensile strength. They vitrify usually at a low temperature, cone 2 or 4, have a low fire shrinkage, and burn to a dense red body. In Ohio a mixture of low-grade fire-clay and shale is sometimes preferred."

Terra Cotta Clays.—"Terra Cotta is made from a great num-

*Op. cit.

ber of different clays, but most manufacturers of this material are now using fire-clays, for these give the best results at the temperatures (cone 6-8) attained in their kilns. The color of the body of the burned mixture is usually buff, the exterior or surface color being due to an application of slip to the outside of the ware. A few terra-cotta makers use low-grade red-burning clays or shales. . . . Clay for terra cotta should burn to a hard body at a moderately high temperature, say 2,300 degrees F., producing a nearly impervious product. While it is desirable to have a vitrifiable clay, the burning of the body is seldom carried to this point for the reason that it is accompanied by too much risk of cracking by overshrinkage. Accordingly, it is customary to use a semi-refractory clay which is burned to a hard body, but not an impervious one."

Brick Clays.—"Pressed or ornamental brick are often molded from refractory or semi-refractory clays, because the buff product thus obtained is very popular, and, furthermore, the buff color makes a good base with which artificial coloring material may be mixed for the production of many other shades. Red clays are still used to some extent, but the demand for them is not nearly as great as formerly. Whatever the class of clay used for pressed brick, uniformity of shade and freedom from discoloration are essential features of the burned product. The discoloration is due to improper mixing or the presence of soluble compounds in the clay, which form a scum on the surface. The physical properties of the clay are of much importance. High refractoriness is not essential, but since straightness of outline is called for, clays of low shrinkage are preferred. Excessively plastic material is undesirable where the stiff mud process is employed, but for dry press brick the plastic qualities of the clay do not play so important a role. Clays of streaky character are often avoided unless they mix readily in the machine.

"Common brick are made from almost any kind of clay, ranging from the calcareous, pebbly clays found in the regions around the Great Lakes to the impure, ferruginous, residual clays found all over the South. . . . A clay to be used for the manufacture of common brick should burn red if possible, since there is then more possibility of its burning dense at a comparatively low temperature and thus avoiding the use of

too much fuel. Most brick clays are burned to about cone 0.05, and at this temperature the clay commonly shows incipient fusion. Good brick clays should burn hard at a temperature of not over 2,000 degrees F., namely, at cone 1, or preferably lower. This means the presence of sufficient fluxing material to bind the clay grains together into a hard body when burned. Large sand grains and pebbles are undesirable, for they tend to make the product porous and weak. The best results are commonly obtained with clays carrying from 5 to 7 per cent. of ferric oxide."

Earthenware Clays.—"Many of the smoother surface clays employed in making common brick are also found satisfactory for the manufacture of earthenware. The materials needed are such as will form a mass of good plasticity with water, will turn readily on the potter's wheel, and will burn to a porous body without excessive shrinkage. The clays used are commonly the less gritty sedimentary clays, for the low price of the ware seldom permits the expense of washing."

Paper Clays.—"These form a type of clay much used by paper manufacturers and having special qualities. Since the clays are not to be molded or burned, plasticity and behavior under fire are of no importance. The great essentials are whiteness of color and freedom from grit. The former property must be originally possessed by the clay. The percentage of grit, however, can often be lowered if the color is good."

A description of methods of manufacture of the various clay products is reserved for a succeeding bulletin.

Clays in Hardin County.

From a line dividing Hardin county bilaterally from north to south there are no clays of much economic importance in the area of the eastern half. Over that portion of the county, limestones and shales are the only rocks of the Lower Carboniferous exposed, and it has already been mentioned that over the territory covered by this report, few valuable clays have been found except in connection with a sandstone formation.

Of course, at places over the eastern area there are fairly

good exposures of the ordinary red brick clay, which is a result of decomposed limestone.

The greater portion of limestone exposure in the county is St. Louis, but in the northeastern portion, near Rolling Fork and Salt river, some of the lower limestones are exposed.

Around West Point there is found a white clay which proves valuable for the manufacture of Portland cement, and there are deposits somewhat similar in appearance near Stithton.

The high lands in the western half of the county are capped with Big Clifty Sandstone, while some of the highest hills contain outliers of the Conglomerate Sandstone. At the base of these hills, the St. Louis Limestone is exposed, and it is between the St. Louis and the Big Clifty, over this section, that the majority of the clays of Hardin county are found.

THE WEST POINT CLAYS.—At places in the bottoms of the Ohio river around West Point, noticeable on the farm of Mr. William T. Turner just west of the town, the soil is underlaid by a light colored plastic clay with a thickness of five or six feet. The color varies at different points.

The low meadow lands east of the mouth of Salt river, in Jefferson county, have a similar subsoil, but with less impurities. It is this material which is to be used in the manufacture of Portland cement at River View, Jefferson county, Ky., by the Kosmos Portland Cement Co.

Following is the analysis of this clay as furnished by the superintendent, Mr. Wm. H. Baker, made by B. Cushman, of Cornell University:

	Per cent.
Alumina	20.02
Silica	63.45
Ferric oxide	4.63
Lime	0.47
Magnesia	0.98

The oolitic limestone which is ground and mixed with this material has the following composition:

	Per cent.
Calcium carbonate	98.49
Magnesium carbonate	0.42
Silica	0.37
Alumina	0.12
Ferric oxide	0.11

THE H. W. RAHM PLACE.—The clay exposures on this place are typical of the clayey subsoil near Stithton.

Mr. Rahm's farm is about one mile north of Stithton, and lies just west of the I. C. R. R. This is a low level territory underlaid by a light colored clay about five feet in thickness, which has been exposed on this farm by deep postholes, excavation of ponds, etc.

The section exposed at this point follows:

1. Soil ..... 2½ ft.
2. Light colored clay..... ..... 2 ft.
3. St. Louis Limestone.

The soil grades gradually into the silicious material below, but is at places much thicker than at others.

Following is the analysis made for the Survey by Burk and Lyon, Louisville, Ky.:

Sample, light gray clay, from farm of H. W. Rahm, one mile north of Stithton. Collected by J. H. Gardner:

	Per cent.
Hygroscopic moisture	1.80
Combined water	4.69
Silica	77.33
Alumina	9.37
Ferric oxide	3.11
Lime	1.10
Magnesia	0.02
Potash and soda	2.12
Titanium dioxide	1.11
Sulphur trioxide	0.48
	101.13

THE J. B. JENKINS PLACE.—This farm is about one and a quarter miles south of Stephensburg, on the I. C. R. R.

The clay exposures here are around a high ridge at the southern part of the farm, and a section of the exposures here shows the following:

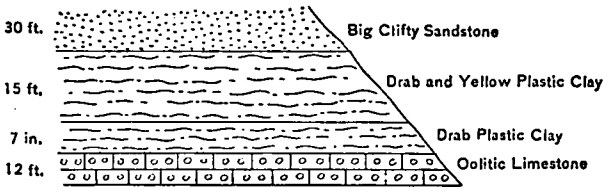
1. Big Clifty Sandstone.
2. Yellow plastic clay..... 2 ft.
3. Drab plastic clay..... 14 ft.
4. Oolitic limestone..... 20 ft.

The yellowish clay is very plastic, fairly smooth, and contains a large percentage of iron. The drab plastic clay is fine grained, homogeneous and of large enough quantity to be easily mined.

This is seemingly a valuable clay for the manufacture of tiling, sewer pipe, etc., and possibly would make a real nice brick.

THE TAYLOR JEFFRIES PLACE.—Mr. Jeffries' farm is one and a half miles north of East View, adjacent to and east of the I. C. R. R.

At the foot of a high hill in the central part of his farm and on other hills at the same elevation just east of there the following section is exposed:



The various colors, if ground together, ought to produce a material which would make a nice brick or tiling. The deposit is free from sand or gravel and probably does not contain enough iron to injure it, though there is enough to cause the product to burn red or brownish, perhaps.

THE JOSEPH LILLY AND ADJACENT PLACES.—The farm of Mr. Joseph Lilly is one the Elizabethtown and Meeting Creek Road one mile northwest of East View.

On this farm and several adjoining ones there are exposures of drab plastic clay. The thickness of the deposits could not be accurately determined at any one place, on account of vegetation, but the exposures range from two to six feet at places.

A typical section of these exposures here is as follows:

1. Big Clifty Sandstone..... 20 ft.
2. Drab plastic clay..... 5 ft.
3. St. Louis Limestone at base of hill.

Similar exposures were found on the land of Mr. Fred Hifner on the south, Schlange Bros. on the east, J. M. Kinkead on the north, and E. R. Robinson on the west.

This is a good quality of drab plastic clay, free from impurities and possibly valuable for sewers, low grade pottery or earthen ware.

THE S. H. RICHARDSON PLACE.—This farm is on the Elizabethtown and Meeting Creek Road about three miles and a half northwest of East View.

This land is at a high elevation, with Big Clifty Sandstone as the surface rock. One deep hollow extends down to the St. Louis Limestone, and here there is a deposit of yellow plastic clay with an exposure of four feet. It is a good quality of yellow clay and might be used for terra cotta. It is free from mineral impurities and is quite plastic when wet.

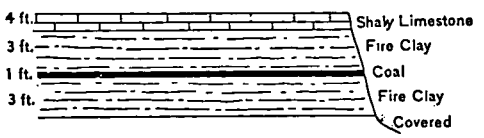
At this place we get the following section:

1. Big Clifty Sandstone..... 80 ft.
2. Yellow plastic clay..... 4 ft.
3. St. Louis Limestone..... 15 ft.

This deposit is very inconvenient, being exposed in a deep hollow. Considerable expense would be necessary before the material could be gotten to a place of easy transport. The construction of an incline would perhaps simplify the proposition.

THE J. D. BARNES PLACE.—Mr. Barnes' farm is on the Elizabethtown and Meeting Creek Road, two miles and a half west of East View.

At a spring three quarters of a mile south of the above mentioned road, the following section was taken:



This thin stratum of coal is no indication that coal occurs thereabouts in paying quantities, but is interesting from a geological standpoint. The St. Louis Limestone is not exposed here, but from barometric readings is not many feet beneath the surface.

The "fire clay" contains too great a quantity of impurities to be valuable for refractory qualities. It is not a fire clay in

the true sense of the term. Perhaps it should be called a soft, shaly clay resembling fire clay.

ILLINOIS CENTRAL RAILROAD DEPOSIT.—There is a deposit of drab plastic clay exposed in the I. C. R. R. cut, about two hundred yards south of the station at East View. This is a short cut across a ridge which runs at right angles to the railroad and extends back into high lands on either side. The deposit is twelve feet thick.

At this cut, the following section is exposed:

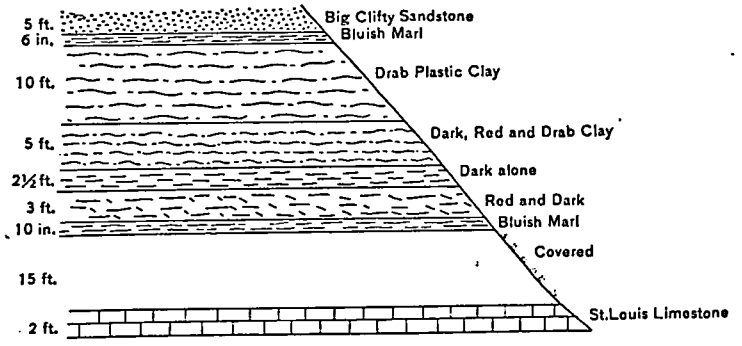
1. Big Clifty sandstone..... 15 ft.
2. Drab plastic clay..... 12 ft.
3. Blue, coarse-grained St. Louis Limestone..... 8 ft.
4. Oolitic limestone (St. Louis)..... 10 ft.

Several years ago, a number of tons of this clay were shipped to Bannon & Co., Louisville, for the purpose of making piping. The clay was reported too fusible, however, and the mining was discontinued.

By the mixing of a small percentage of silica, this material would be rendered more refractory and could probably be used profitably and with good results.

THE WASH NICHOLLS PLACE.—The farm of Mr. Wash Nicholls is on the East View and Meeting Creek Road two miles west of East View.

Alongside the above-mentioned road there is quite an extensive and varied clay exposure, as shown by the following section:



The drab plastic layer at the top is a valuable clay for agri-

cultural structures, sewers, etc. The red is very ochreous and might be valuable for the manufacture of paint if separated from the dark and drab. The dark clay is plastic and would likely burn to a similar colored material as the drab plastic layer at the top. It is also probable that a mixture of the whole deposit could be profitably worked, provided the marls do not furnish an excess of lime.

THE HARRISON ASHLOCK PLACE.—Mr. Ashlock's farm is on the East View and Meeting Creek Road about two miles west of East View.

This deposit is of limited extent, but interesting because of its geological location. It is not found at the base of the Big Clifty, as are most of the deposits of this section, but is higher up in the series.

The following section was taken at this point:

1. Thin layer of sandstone	10	ft.
2. Bluish plastic clay	2½	ft.
3. Stratum of limestone	40	ft.
4. Big Clifty Sandstone	40	ft.

This deposit is of too limited thickness and horizontal extent to be of much commercial interest. It occurs at the same geological horizon as do many of the plastic clays of Grayson county, namely, above a limestone at the top of the Big Clifty Sandstone. This limestone is in all probability an equivalent of the Tribune Limestone identified by E. O. Ulrich in Crittenden and Livingston counties.*

THE CHARLES NELSON AND JAMES LASLEY PLACE.—This place is on the Summit and Webb's Mill Road, two miles south of Summit.

Near the above-named road, which crosses the land owned by these gentlemen, there is an exposure of yellow plastic clay and fire-clay.† This yellow clay shows an exposure of four feet, but on account of timber growth no accurate measurements of the

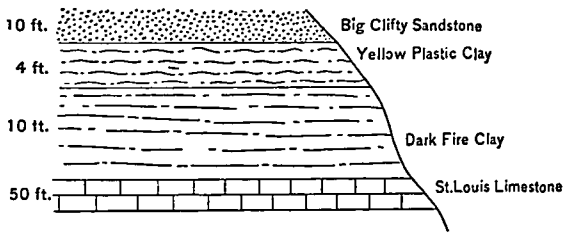
* As yet, it is an open question whether correlations can be made on the eastern rim of the Western Coalfield with the thinner members (such as the Tribune limestone) of the Chester group as the latter has been subdivided, by Mr. Ulrich, in Crittenden County.—C. J. N.

† Mr. Gardner, apparently as a rule, uses the term "fire-clay" simply in contradistinction to "plastic" clay; using it to designate a semi-plastic or non-plastic clay which may be in some degree refractory.—C. J. N.

PLASTIC CLAY. HARRISON ASHLOCK PLACE, EAST VIEW, HARDIN COUNTY.

thickness could be made. The dark clay shows a thickness of ten feet, and where exposed breaks up into small flakes.

At this point, the following section is exposed:



This yellow clay is likely a very valuable clay for tiles of various kinds and for piping. The fire-clay is, however, not refractory enough to be valuable for its fire-proof properties, and is not a fire-clay in the true sense.

THE WILLIAM DEAVER PLACE.—This farm is in what is known as Deaver's Hollow, on the Summit and Meeting Creek Road, three miles west of Summit. The picturesque little place is surrounded by high cliffs of Big Clifty Sandstone, while St. Louis Limestone is only a few feet beneath the surface. On the east side of his farm there is a low hill which rises gradually to the cliffs of sandstone and includes a semi-circular area of about five acres. This area is underlaid by a deposit of drab plastic clay with an exposure of about four feet.

The following section is exposed at this point:

1. Big Clifty Sandstone..... 90 ft.
2. Drab plastic clay..... 4 ft.
3. Covered ..... 10 ft.
4. St. Louis Limestone..... 3 ft.

This clay is mixed with earthy impurities at the exposure, but would show to much better advantage if exposed by a shaft, and probably prove valuable.

THE CHARLES CARBY PLACE.—The exposure on this place is just east of the White Mills and Millerstown Road, near the corner of the three counties of Grayson, Hardin and Hart.

At this point, the following section is exposed:

1. Soil ..... 3 ft.
2. Dark, shaly clay..... 12 ft.
3. Top layer of St. Louis..... 20 ft.

This dark clay is composed of thin layers and weathers to small flakes. It is rather on the order of a marl in general appearance, but in all probability contains a very low percentage of lime. It might make an excellent brick if ground, or, mixed with a pure limestone, might contain the proper percentages of silica, alumina, and iron for the manufacture of Portland cement.

THE GIDEON MCCLURE PLACE.—This place is on the White Mills and Millerstown Road, about two miles from Millerstown. Along the named road and around the hills on either side, there are exposures of a drab plastic clay at the top of the St. Louis Limestone.

The following is the average section here:

1. Covered	2 ft.
2. Drab plastic clay	6 ft.
3. St. Louis Limestone	10 ft.

This deposit is colored by iron, at places, which has leached in from above. The deposit is not altogether free from grit, and is slightly spangled with manganese. It may prove useful, however, for earthenware or agricultural structures, etc. At some places, the deposit is much thicker than is given in the section.

Clays of Hart County.

The clay territory of Hart county covers the greater portion of the county, with the exception of the area south of Green river. The area south of the river shows only limestone exposures and consequently only the ordinary red plastic clay with a large percentage of iron, which results from limestone decomposition.

Over the northern portion, there are many Lower Carboniferous exposures which naturally appear around the margin of the coal field and, with them, valuable clays.

In the greater portion of the western part, the low lands and stream bottoms show exposures of St. Louis Limestone. The low hills contain only sands and limestones of the Chester

Group, the sandstone at the base of which is known in the Kentucky reports as the Big Clifty Sandstone.

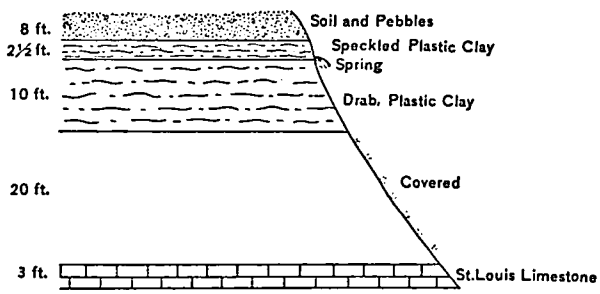
The high hills of this section are capped with loose pebbles and old eroded cliffs of the Conglomerate Sandstone, which is the basal formation of the Upper Carboniferous.

Over a section of several square miles east of the L. & N. Railroad, in the Bonnieville region, there is a very marked unconformity. Here the Chester Group is scarcely, if at all, represented at places, and the Conglomerate Sandstone rests almost upon the St. Louis Limestone. It is over this section that the most valuable white clays in the county occur. This fact is brought out by a notice of the sections at each deposit.

THE J. B. ISAACS PLACE.—This place is on the Bonnieville and Munfordville Road, four miles southeast of Bonnieville. On the named farm, there is a small spring which issues from between layers of plastic clay. This clay is of a gray color with small red specks.

There is an exposure of two and a half feet above the spring. This layer contains a considerable amount of organic matter and iron, while below the spring the clay is of purer quality and shows an exposure of ten feet.

Here the following section is exposed:



This clay is free from grit, quite porous, and likely a valuable material for tiling or fire brick. Following is an analysis of the clay made for the Survey by Burk & Lyon, Louisville, Ky.:

Sample, a reddish brown, or drab speckled, plastic clay,

from farm of J. B. Isaacs, on Bonnieville road, four miles southeast of Bonnieville. Collected by J. H. Gardner.

	Per cent.
Hygroscopic moisture	4.62
Combined water	6.86
Silica	54.07
Alumina	22.60
Ferric oxide	5.04
Lime	0.28
Magnesia	0.50
Potash and soda	4.61
Titanium dioxide	0.93
Sulphur trioxide	0.27
	99.78

A rational analysis of the foregoing shows the following:

Clay substance	84.58
Quartz	14.14
Feldspathic detritus	1.28
	100.00

THE JOHNSON-HAWKINS PLACE.—This area of clay exposures is on the Bonnieville and Munfordville Road, four miles southeast of Bonnieville and two miles east of Dividing Ridge Station.

On the farm of Mr. Charles Johnson, there is an exposure of dark clay resembling fire clay, in a well thirty feet deep. The clay "sets in" five feet from the top and is eighteen feet thick.

Across on the land of Mrs. Mary L. Hawkins, a half mile to the north and practically at the same elevation, there is a similar exposure made by a shaft.

Here the following section was taken:

1. Soil	5 ft.
2. Dark clay	18 ft.
3. St. Louis Limestone.	

This deposit is very persistent horizontally, but is likely too fusible for fire proof purposes. It is plastic when wet and might be profitably worked for tiling, sewer pipes, pressed brick, etc.

THE MOSS KAOLIN FIELD.—What is here termed the "Moss Kaolin Field" is an area of several thousand acres in which kaolin outcroppings and exposures are found. It is so designated because the most important and original exposure is on the land of Mr. Philip Moss.

Over this field, we find the Conglomerate Sandstone immediately above the clay and the St. Louis Limestone only a few feet below.

Beginning at a point on the Hammonsville and Munfordville Road, about three miles southeast of Bonnieville, and extending around the field to the north, east, and south, the farms showing signs and exposures of kaolin of a similar variety and in a similar mode of occurrence are as follows: Messrs. Samuel Murray, J. S. Knight Philip Moss, William Gibson, Samuel Devore, J. R. Adcock, Charles Bolton, C. R. Bolton, James A. Hodges and Wood Buckner.

On Mr. J. S. Knight, small white outcroppings or pieces of kaolin are found over the surface and through the soil around the general level of the base of the Conglomerate Sandstone. No definite bed has been located here, however.

In a similar manner signs are shown on Messrs. William Gibson, J. R. Adcock and C. R. Bolton.

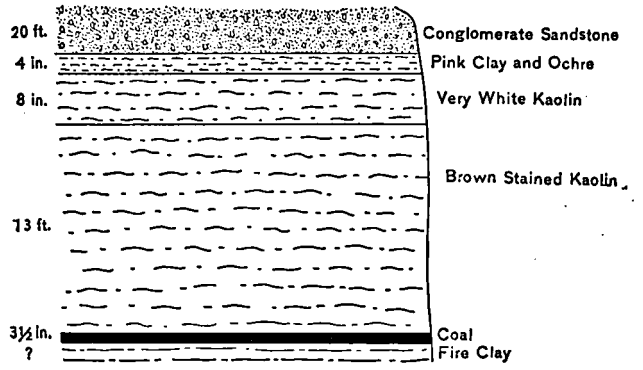
On the farm of Mr. Samuel Devore there is a deposit of red ochreous material about three feet thick underlaid by an impure, yellowish variety of kaolin of undetermined thickness.

The reports follow in regular order of the exposures on Messrs. Philip Moss, Samuel Murray, Charles E. Bolton, James A. Hodges and Wood Buckner:

THE PHILIP MOSS PLACE.—Important exposures in the area under consideration are the original ones on the farm of Mr. Philip Moss.

Mr. Moss lives on a neighborhood road to Bonnieville, about five miles southeast of that town. On his farm there are two important exposures. The first is just west of his home, and here a semi-circular pit has been dug about one hundred feet long and ten feet deep, which gives a good exposure of the deposit.

The following is a section here:



The St. Louis Limestone evidently occurs only a short depth below the under clay, called "fire clay," as shown by its level at other places. It is not exposed at this point.

The quality of this clay is very similar to the material exposed half a mile west of the described exposure. Here the following exposure was taken at a shaft:

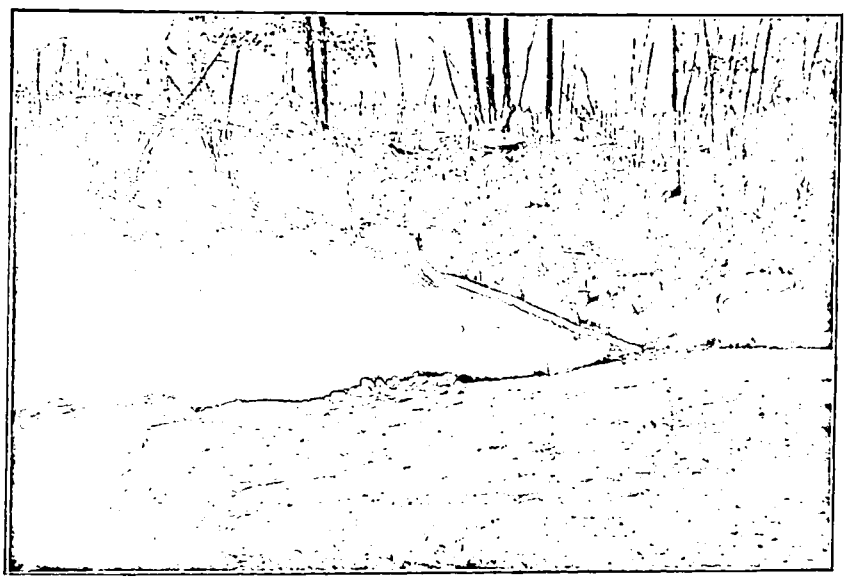
1.	Soil and Conglomerate pebbles	8 ft.
2.	Kaolin, slightly stained	8 ft.
3.	Chert layer (segregations, perhaps)	3 in.
4.	Kaolin, slightly stained	1 ft.
5.	Coal	½ in.
6.	Under-clay	?

This exposure is at the same elevation barometrically and geologically as the one near Mr. Moss's residence.

Experiments have proven this white kaolin to be an excellent quality of clay for the manufacture of fine china ware and porcelain.

Following is an analysis of the unwashed kaolin from the shaft on the Philip Moss place, made by Dr. A. M. Peter, Survey Chemist:

	Per cent.
Moisture	2.39
Ignition	12.68
Silica	48.09
Alumina	34.66
Ferric oxide	0.78
Lime	0.27
Magnesia	0.23
Potash	0.74
Soda	0.30
Titanic oxide	0.25
	100.39



FIRST KAOLIN MINE ON PHILIP MOSS PLACE, HART COUNTY.

The foregoing analysis is of an averaged sample collected by W.U. Grider from exposure No. 1. See remarks under analysis of clay from S. J. Murray's place.

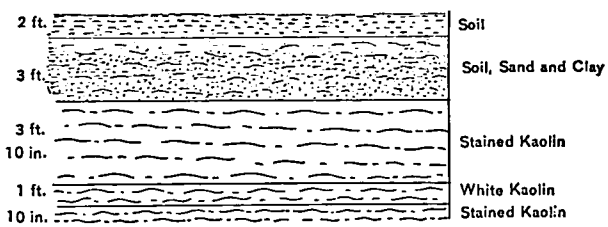
Following is an analysis of an averaged sample taken from the long pit by Mr. Grider. Sample mostly white, soft and very porous. One piece was much stained by iron.

Analysis of air-dried sample by A. M. Peter:

	Per cent.
Moisture	2.71
Ignition	16.69
Silica	42.32
Alumina	36.92
Ferric oxide	0.62
Lime	0.21
Magnesia	0.08
Potash	0.47
Soda	0.18
Titannic oxide	Trace
Sulphuric anhydride	Trace
	100.25

THE S. J. MURRAY PLACE.—The farm of Mr. S. J. Murray is on a country road or "shun pike" from Bonnieville to Munfordville, three miles southeast of Bonnieville.

A valuable deposit of kaolin has been exposed on this place by a shaft about fifteen feet deep. The section here is as follows:



No limestone nor sandstone is exposed at this point, but according to aneroid readings the deposit is just above the St. Louis Limestone. The clay termed "stained kaolin" is slightly colored yellowish with iron oxide; probably not to such large extent, however, that it can not be washed white, or will not burn white. These purest white layers contain no injurious im-

purities and require no admixture of foreign material in order to make it suitable for the manufacture of fine porcelain or china ware.

The hillsides over an area of four or five acres show signs of this deposit.

Following is an analysis of the unwashed clay, by Dr. A. M. Peter, Chemist for the Survey:

	Per cent.
Moisture	2.99
Ignition	14.80
Silica	43.31
Alumina	37.93
Ferric oxide	0.32
Lime	0.23
Magnesia	0.13
Potash	0.25
Soda	0.12
Titanic oxide	0.10
Sulphuric anhydride	A trace
	100.18

The sample of which the analysis was made was taken by W. U. Grider, and showed much iron stain. Some of the pieces were rather hard and greenish-white.

Commenting upon the samples analyzed from the Moss and Murray places, Dr. Peter says: "These ought to be fine porcelain clays, as they have nearly the same composition as kaolin. Possibly they might be used as fuller's earth, but this could only be determined by practical test." He also notes that the white pieces are perfectly infusible, even in the thinnest splinters, in the blowpipe flame.

THE CHARLES E. BOLTON PLACE.—Mr. Bolton's farm is near the Hammonsville and Munfordville Road on a neighborhood road to Bonnieville, five miles southeast of that station.

The deposit here is interesting from a geological point of view as well as a commercial one. The clay is kaolin stained brown near the surface by the leaching action of water. The deposit is about three feet thick, underlaid with "fireclay." The "fireclay" has a probable thickness of five feet. The exposure is in a low valley or hollow between high hills, and at this point the deposit is turned on edge almost perpendicularly. There

GENERAL VIEW OF KAOLIN MINE ON S. J. MURRAY PLACE, BONNIEVILLE, HART COUNTY.

is a dark humus soil covering the deposit horizontally to a depth of two feet or more. On one side of the exposure there are exposures of sandstone, and on the other side limestone; but the high hills around show only limestone cliffs. The occurrence and position of this clay is difficult to explain. There are no signs of faulting, but there has evidently been some kind of disturbance; probably a local sinking which gave the deposit its peculiar position at the point of exposure. It is likely that the clay at this place is only the remains of the main deposit once much higher up in the geological formation.*

Following are analyses of the unwashed clay, made for the Survey by Burk & Lyon:

	Per cent.
Hydroscopic moisture	2.82
Combined water	14.60
Silica	44.16
Alumina	37.34
Ferric oxide	1.28
Lime	0.25
Magnesia	Trace
Potash and soda	0.53
Titanium dioxide	Trace
Sulphur trioxide	0.31
	101.29

Relational analysis:

Clay substance	97.98
Quartz	1.85
Feldspathic detritus	0.17
	100.00

THE JAMES A. HODGES PLACE.—One characteristic of the white clays of this section is that they break up into small angular pieces when exposed to the weather. These pieces are often found over the surface and mixed with the soil above a kaolin deposit, and are known as "outcroppings."

Nice outcroppings of kaolin are found on the farm of Mr. James A. Hodges, near the Bonnieville and Munfordville Road, two miles east of Bonnieville. On this farm there is a hollow two or three hundred yards long which shows these particles of clay around the inclosing hills. They occur along a belt, with

* The "disturbance" may be due to the subsidence of the roof of a former cavern.—C. J. N.

a perpendicular thickness of about eight feet. No pits nor borings have been made into the deposit, but the indications are very flatteringly in favor of a nice deposit here.

The small pieces are of fine quality and very similar to the material found at other places in the field. The deposit is at the base of the Conglomerate Sandstone and here the following section was taken:

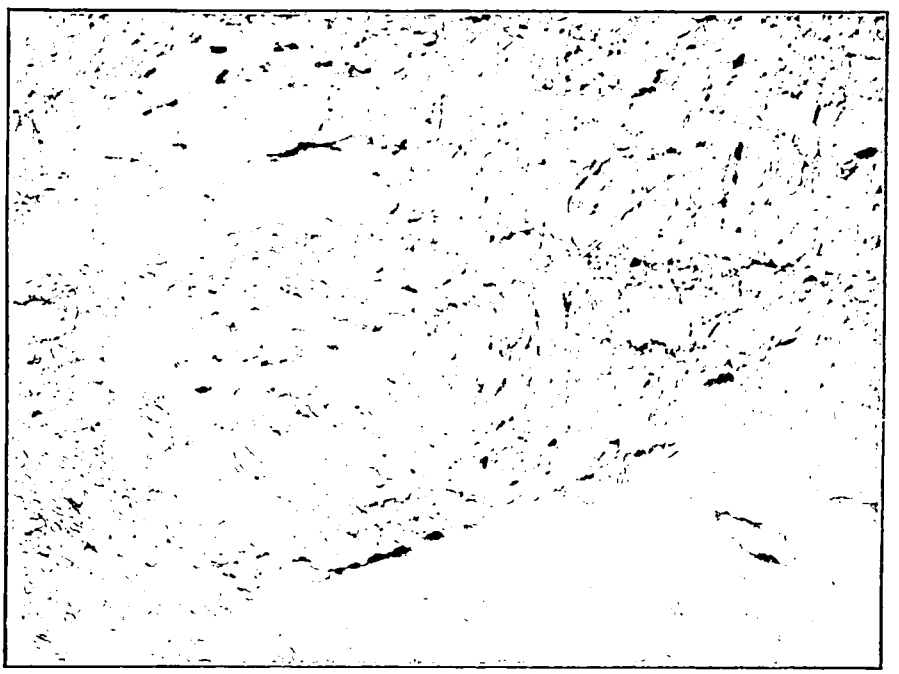
1. Covered, Conglomerate pebbles and soil.
2. Kaolin "outcroppings"..... 8 ft.
3. Covered ..... 30 ft.
4. Limestone, covered (St. Louis).

An analysis of this clay (unwashed), by Dr. A. M. Peter, Survey Chemist, is as follows:

	Per cent.
Moisture	3.77
Ignition (combined water and volatile matter)	15.76
Silica	37.86
Alumina	35.94
Ferric oxide	3.92
Lime	0.74
Magnesia	0.35
Potash	0.37
Soda	0.08
Phosphorus pentoxide	0.26
Sulphur trioxide and titanium dioxide	Traces
Total	99.05

Dr. Peter makes the following comments on the analysis: "The proportion of iron is rather large in this clay. It could no doubt be used with more sandy material to produce terra cotta of very delicate shades."

THE H. W. BUCKNER PLACE.—There are indications of kaolin on the farm of Mr. H. W. Buckner five miles southeast of Bonnieville. A small pit, about four feet deep, was dug into the clay at this exposure, but no definite deposit was located. Toward the top the small white pieces were mixed with soil, but lower down they were in prevailing quantity. The occurrence is in the same geological horizon as the other white clay deposits of this immediate territory; namely, at the base of the Conglomerate Sandstone. The surface is covered with soil and vegetation



KAOLIN WALL, SHOWING BANDED CHARACTER OF DEPOSIT, SECOND MINE PHILIP MOSS PLACE, HART COUNTY.

here to such an extent that no good section can be given of the deposit.

The above described places, all showing a similar variety of clay and occurring in the same vicinity, have given rise to the name "Moss Kaolin Field."

THE SAMUEL GOLDSMITH PLACE.—This farm is one mile east of Dividing Ridge, on a country road to Munfordville.

There is a clay exposed here of the plastic variety which has a pinkish-drab color with yellow spots due to iron. This deposit is in the form of a sharp anticlinal fold. A pit has been sunk into the deposit on each side of the axis only ten feet apart. Above the clay there is eight feet of sand colored bright red with iron oxide. It is from this sand that iron has leached into the clay below, giving it a spangled appearance. Below the deposit there is an exposure of St. Louis Limestone.

The following is the section at the exposure:

1. Soil	1 ft.
2. Red sand (Conglomerate)	8 ft.
3. Pinkish-drab clay	5 ft.
4. Covered	15 ft.
5. St. Louis Limestone.	

This clay is free from grit and would probably burn to a nice tile regardless of the iron which it contains.

THE S. T. ISAACS PLACE.—A deposit of plastic or pinkish-drab clay is exposed on the farm of Mr. S. T. Isaacs, near the Bonnieville and Munfordville Road, three miles southeast of Bonnieville.

In a shallow gully, the top of the bed is exposed only for a short distance. An opening was made with a spade to the depth of two feet, but the thickness of the deposit is not definitely known.

There is something like the following section here:

1. Conglomerate pebbles and soil on hill.	
2. Plastic clay, exposed	25 ft.
3. Covered	25 ft.
4. St. Louis Limestone	3 ft.

This is a good quality of plastic clay doubtless for tiling, earthenware, brick, etc. Near the surface the clay is somewhat

gritty, but this is likely due to the sand having been washed into it from above by rains.

THE GEORGE KNIGHT PLACE.—This place is four miles east of Bonnieville on a neighborhood road from Bonnieville to Frenchman's Knob.

The exposure here is on the side of a large hill. About two feet from the top of the deposit, there issues a small spring, and the drab plastic clay is exposed two or three feet on down below the spring.

Small gullies around the same hill and adjacent hills show very similar exposures.

The following is the section here:

1. Soil and pebbles	4 ft.
2. Drab, plastic clay	2 ft.
Spring.	
3. Drab, plastic clay	3 ft.
4. Covered.	

Probably a valuoble clay for drain tiles, water conduits, sewers, etc.

THE J. F. AND J. W. GADDIE PLACE.—This place is near the Hammonsville and Munfordville Road about three miles southeast of Bonnieville. There is an interesting exposure of clays here along a small branch which heads at "Gaddie Spring." Along this branch we get the following section:

1. Conglomerate sandstone	40 ft.
2. Drab, plastic clay	½ ft.
Spring.	
3. Shaly limestone	3 ft.
4. Dark, sandy shale	5 ft.
5. Covered	20 ft.
6. Drab, plastic clay	1 ft.
7. Yellow, plastic clay	3 ft.
8. Covered.	

The dark shale occurring near the top of this section is composed principally of sand in a fine state of division—so fine that the material is plastic when wet.

The plastic clays are sandy near the surface, but purer lower down.

THE G. R. THORPE PLACE.—This farm is on the Hammonsville and Munfordville road about three and a half miles northeast of Bonnieville and one mile southeast of Wabash. Two deep intersecting gullies expose three different layers of clay in a deposit here.

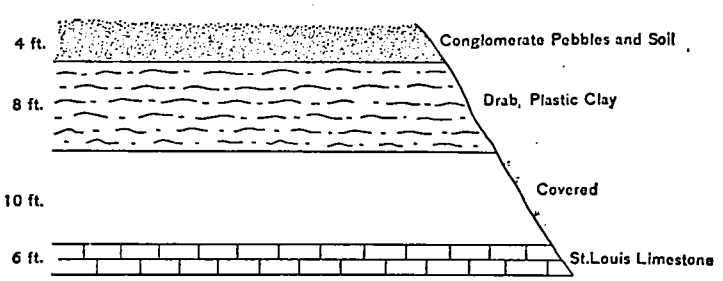
At the exposure the following section is exposed:

1. Soil and Conglomerate sand..... 20 ft.
2. Yellow, plastic clay..... 1½ ft.
3. Pink, plastic clay..... 1 ft.
4. Drab, plastic clay..... 3 ft.
5. Covered.

The clay shows at other points on surrounding hills at the same elevation. This plastic clay is similar to other plastic clays in this locality and valuable for the same purposes.

THE J. B. HODGES PLACE.—Mr. Hodges' farm is on the Hammonsville and Bonnieville Road and mile and a half east of Wabash. The main portion of the farm is low, with St. Louis Limestone exposures, but toward the south the land rises and breaks into hills capped with Conglomerate Sandstone.

On the hills to the south, there are exposures of a very fat clay of a drab color. The true thickness of the deposit is not determined, but the following is a section of the deposit at a cistern:



In the days of early settlements in Hart county, this clay was mined for the purpose of manufacturing hand-made crocks and jars.

THE J. CASWELL PLACE.—This place is on the Bonnieville and Hammonsville Road about four and a half miles northeast of Bonnieville and half a mile east of Wabash.

There are several exposures here of a clay deposit. Gullies along a ridge expose the different layers at numerous places over an area of ten or fifteen acres, giving the following section:

1. Soil	4	ft.
2. Drab, plastic clay	3	ft.
3. Pink, plastic clay	2½	ft.
4. Dark, plastic clay	4	ft.
5. Covered	15	ft.
6. St. Louis Limestone	6	ft.

These clay layers are very free from gritty or mineral impurities and are valuable clays for the manufacture of earthenware, etc. The dark layer at the bottom of the gullies is a plastic clay, but similar in appearance to the fireclays.

Following are analyses, made for the Survey by Burk & Lynn:

Sample, a dark clay from farm of J. Caswell, on Bonnieville and Hammonsville Road, four and a half miles east of Bonnieville, Hart county. No. 4 of the vertical section.

	Per cent.
Hygroscopic moisture	3.05
Combined water	7.69
Silica	56.73
Alumina	24.71
Ferric oxide	3.72
Lime	0.38
Magnesia	0.15
Potash and soda	3.04
Titanium dioxide	0.79
Sulphur trioxide	0.84
	101.10

Analyses, ultimate and rational, of the pink plastic clay, No. 3 of the section, are as follows:

Hygroscopic moisture	2.85
Combined water	6.96
Silica	60.52
Alumina	20.99
Ferric oxide	3.41
Lime	0.21
Magnesia	0.14
Potash and soda	2.85
Titanium dioxide	1.10
Sulphur trioxide	0.49
	99.52

The rational analysis gives:

Clay substance	66.35
Quartz	30.64
Feldspathic detritus	3.01
	100.00

THE JAMES RIGGS PLACE.—Mr. Riggs lives near the Bonnieville and Priceville Road, about three miles west of Bonnieville. On this farm there is an exposure of plastic clay of good quality. Around a large hill east of his home, there are exposures of what seems to be an extensive deposit of clay.

There is something like the following section here:

1. Hill, covered with soil and sand.	
2. Drab, plastic clay	15 ft.
3. Covered	10 ft.
4. St. Louis Limestone	14 ft.

This clay possesses a fine body. It is very plastic and little mixed with foreign impurities. The color is a light drab and but for its plasticity might be taken for impure kaolin. This ought to be an excellent clay for the manufacture of tiling, conduits, flooring, etc., and possibly encaustic or vitrified wares.

THE STAMP-CLARK EXPOSURES.—These exposures are just outside the town of Bonnieville, to the west on either side of the Bonnieville and Priceville Road. There are exposures of a deposit here which is more interesting from a geological point of view than from a commercial one.

These exposures are in the plane of a normal fault. The St. Louis Limestone and Chester Sandstones are turned on edge and a displacement occurs of about one hundred feet. This clay deposit was formed before the disturbance took place and is faulted in a similar way as are the strata. The fault plane or strike runs in a northeast and southwest direction, dipping southeast. On the west side, next to the St. Louis Limestone, there is a deposit of plastic clay turned on edge, with a thickness of two feet. This deposit is exposed to the north of Mr. J. M. Stamp and to the south of Dr. J. H. Clark. The clay is a very impure variety of drab, plastic clay, and is neither in sufficient quantity nor in a favorable position to be profitably mined. The deposit is evidently very old and certainly of sedimentary origin.

THE ELIZABETH WILSON PLACE.—Mr. Wilson's farm is on the Bonnieville and Cub Run Road, three miles southwest of Bonnieville.

On this place there are very marked exposures of a clay deposit, as shown in several gullies cutting across a ridge.

The following section was taken here:

1. Sandstone ..... 30 ft.
2. Brown, Plastic Clay..... 6 ft.
3. Covered.

This clay contains a considerable percentage of iron and manganese, and will doubtless burn red, in which case it might be valuable as a brick clay or low grade earthenware.

THE J. J. HODGES PLACE.—A deposit of impure yellowish kaolin is found on this farm, but is quite limited in quantity. This farm is one the Bonnieville and Cub Run Road, four miles southeast of Bonnieville. The deposit here is only about one foot thick and is exposed in a large gully which cuts through the Conglomerate down to the St. Louis.

The following section was taken here on the side of a long ridge:

1. Conglomerate Sandstone ..... 20 ft.
2. Yellowish kaolin..... 1 ft.
3. Covered (red sand)..... 10 ft.
4. St. Louis Limestone.

This clay seems to be a good quality of kaolin and could possibly be washed white, but it is not in sufficient quantity to be of commercial interest.

THE WILLIAM PRIDDY PLACE.—Mr. William Priddy lives in Hart county on the Upton and Priceville Road, about six miles west of Upton. A pit has here been dug into the clay, but no definite deposit has been located. The material occurs in irregular layers at the top of the St. Louis.

The following is the section here:

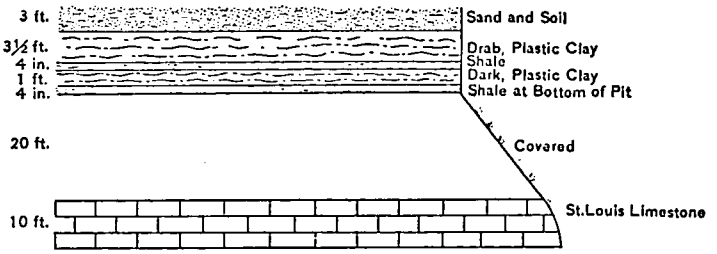
1. Conglomerate pebbles and sand..... 20 ft.
2. Plastic clay and yellow soil..... 5 ft.
3. St. Louis Limestone..... 6 ft.

This clay is of a drab, plastic color and contains a great

quantity of gypsum crystals. These crystals set thickly through the layers, giving it a granular and glistening appearance. On two or three of the immediate hills at the same elevation, we get similar exposures of the same deposit.

THE J. L. ARTTERBURY PLACE.—This place is on the Upton and Priceville Road, three miles southwest of Upton.

There is a deposit of drab, plastic clay here between the St. Louis Limestone and the Big Clifty Sandstone. The clay is exposed at several points along a long ridge. At a pit sunk at one place, the following section was taken:



This is a very impure variety of plastic clay, being mixed to a large extent with iron and manganese oxide.

THE J. S. PRIDDY PLACE.—This farm is on the Upton and Priceville Road about three miles southwest of Upton.

The following is the section at an exposure of drab, plastic clay on Mr. Priddy's place:

1. Covered ..... 5 ft.
2. Drab, plastic clay..... 3 ft., 8 in.
3. Covered ..... 30 ft.
4. St. Louis Limestone.

This clay is a very similar material to that found at numerous places in this territory. At the top the deposit is colored red by iron oxide which has leached in from above. Toward the bottom, the deposit is covered with soil and vegetation to such an extent that the entire thickness was not accurately determined. The amount of impurities present is probably not large enough to injure the clay in the manufacture of tiles, sewers, etc.

THE W. G. W. BUTLER PLACE.—Mr. Butler's farm is about two and a half miles southwest of Upton, on the Upton and

Priceville Road. The Big Clifty Sandstone occurs here in regular position above the St. Louis Limestone. Along a drain which cuts across the exposure, we find two similar deposits exposed. One near the top or just above the Big Clifty; the other at the base next to the St. Louis Limestone.

The following is a section including both deposits of plastic clay:

1. Layers of Chester sandstone	20 ft.
2. Drab, plastic clay	10 ft.
3. White, sandy shale	2 ft.
4. Big Clifty Sandstone	75 ft.
5. Drab, plastic clay	10 ft.
6. White, sandy shale	2 ft.
7. St. Louis Limestone	6 ft.

The clays of these two deposits are very similar. Both are underlaid by similar white, silicious shale. There are no signs of faulting, however; this similarity is merely a coincidence.

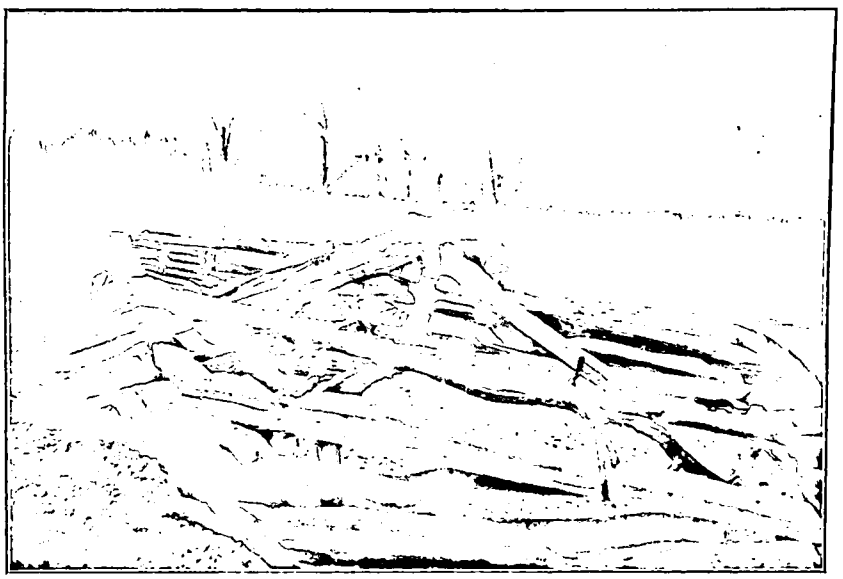
The clay is of excellent quality and very free from any physical impurities.

Following is an analysis of the crude clay, from the upper bed, No. 2, by Dr. A. M. Peter, Survey Chemist:

	Per cent.
Moisture	3.04
Ignition (combined water and volatile matter)	6.05
Silica	61.90
Alumina	19.17
Ferric oxide	3.69
Lime	0.54
Magnesia	1.20
Potash	2.93
Soda	0.11
Phosphorus pentoxide	0.08
Titanium dioxide	1.14
Sulphur trioxide	Trace
Total	99.85

Commenting on the analysis, Dr. Peter says: "This clay should be excellent for making builders' brick, tiles, etc., or for Portland cement."

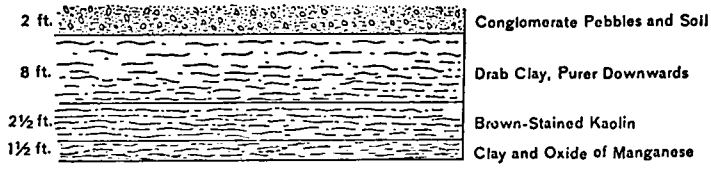
THE J. H. PRIDDY PLACE.—Mr. J. H. Priddy lives about four miles west of Bonnieville on a neighborhood road connecting from Bonnieville with the Upton and Priceville Road.



TYPICAL PROSPECTING PIT. J. H. PRIDDY PLACE, HART COUNTY.

A clay deposit is exposed here as a rim around the top of a high knob known as "Priddy's Knob." The clay is plastic near the top, but becomes lighter in color and more like kaolin toward the bottom.

The following is a section at a shaft on the side of the knob.



This is quite an extensive deposit of clay and doubtless a valuable one. Although it is probable that this clay could not be washed to a sufficient degree of purity for the manufacture of fine china, yet it is of excellent quality for a lower grade pottery, tiling, etc.

THE S. S. HODGES PLACE.—This farm is near the Hammonsville and Munfordville Road, about five miles northeast of Munfordville.

In a field west of Mr. Hodges' home, there is a low depressed hill surrounded by higher ones. This hill and the ones around show exposures of St. Louis Limestone from base to summit. Around the top of the central high land there are signs of kaolin.

We get the following section here:

1. Covered (chert and soil on hill).
2. Layer of iron carbonate..... 4 in.
3. Laminated sand and kaolin..... 3½ ft.
4. Space, with small outcroppings of kaolin..... 1ᶜ ft.
5. St. Louis Limestone..... 6 ft.

No definite deposit has been located here, and it is very probable that the particles are only the remainder, or inheritance so to speak, of a deposit that once existed here at the top of the St. Louis.

THE ALBERT HODGES PLACE.—Mr. Albert Hodges' farm is near the Munfordville and Priceville Road, about four miles northwest of Munfordville and two miles west of Dividing Ridge.

There is a clay exposure on this place at which the following section was taken:

1. Soil and vegetation..... 3 ft.
2. Yellow, plastic clay..... 2 ft.
3. Dark clay..... 2 ft.
4. Covered.

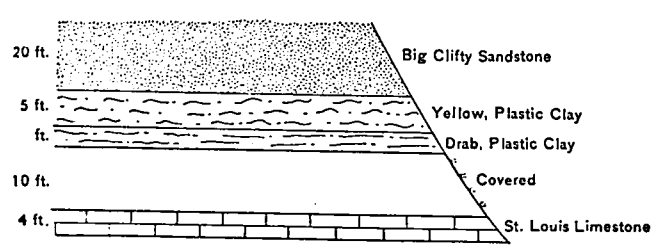
The thickness of this dark clay below is not known, but it probably is three or four feet. A thorough examination could not be made on account of the exposure being along a spring branch where water interfered. The plastic clay is of good quality, so far as the body of the material is concerned, but contains a considerable percentage of iron and manganese perhaps.

THE JAMES LOGSDON PLACE.—The exposure of clay on this farm is along the Munfordville and Cub Run Road, about four miles west of Munfordville.

There is a bold hill at this point which is capped with Conglomerate Sandstone. On the side of this hill, at the base of the named formation, there are gullies exposing only partially a clay deposit. The thickness can not be accurately determined, on account of soil covering, until a shaft or boring is made. The clay is of the plastic variety and has a pinkish drab color. On account of the covering, no definite section can be given at this deposit. Indications, however, favor a nice deposit of plastic clay at this place.

THE JESSE CRADDOCK PLACE.—Mr. Craddock lives on the Cub Run and Priceville road, about two miles from Cub Run.

At numerous places on his farm there are exposures of a deposit of yellow and drab plastic clay. The deposit is at the top of the St. Louis Limestone, giving at the exposure a section as follows:



This clay is very "fat," or plastic. It contains a considerable percentage of iron oxide apparently, and some oxide of manganese. Possibly a good material for the manufacture of earthenware, pipes, etc. The deposit underlies several acres of good land which bears an excellent growth of timber.

THE J. M. WILKERSON PLACE.—Mr. Wilkerson's farm is near the Munfordville and Leitchfield Road, about four miles west of Munfordville and two miles west of Dividing Ridge Station.

Several acres on this farm are underlain by kaolin at the base of the Conglomerate Sandstone. On the slopes the surface is covered with small white pieces which break with a conchoidal fracture and adhere strongly to the tongue. These pieces, or outcroppings, show along belts about ten or fifteen yards wide which is a perpendicular thickness of about ten feet on these slopes.

Small pits have been dug, but not to sufficient depth to show the true nature of the deposit. Some of these shallow pits exposed pieces from the size of a bird's egg to six inches in diameter. These pieces are very pure, white kaolin except for slight stains on the outside due to iron oxide.

There are few exposures here of the rock formations, but according to barometric readings the St. Louis Limestone is only a short depth below.

Following are analyses, ultimate and rational, of this kaolin, made for the Survey by Burk & Lyon:

Sample, a white clay with iron stain on fracture:

	Per cent.
Hygroscopic moisture	4.70
Combined water	14.23
Silica	42.40
Alumina	36.70
Ferric oxide	1.34
Lime	1.04
Magnesia	Trace
Potash and soda	0.36
Titanium dioxide	Trace
Sulphur trioxide	0.16
	100.91

The rational analysis gives:

Clay substance	99.21
Quartz	0.47
Feldspathic detritus	0.32
	100.00

The following is the analysis of a hard clay of bluish-gray color from the farm of Mr. John Wilkerson on the Munfordville and Leitchfield Road near the farm described as the J. M. Wilkerson Place. The clay is of unknown thickness, but very thick. There is probably something like forty feet of this hard, shaly clay. A deep pit was once dug into this deposit, but was not accessible at the time of the examination:

Hygroscopic moisture	3.34
Combined water	5.24
Silica	64.68
Alumina	17.35
Ferric oxide	3.29
Lime	0.26
Magnesia	1.09
Potash and soda	3.74
Titanium dioxide	1.06
Sulphur trioxide	0.28
	100.33

Edmonson County.

In Edmonson county we have represented all the rocks of the Carboniferous Period from the St. Louis Limestone to the Coal Measures.

Over a considerable area in the eastern, southeastern and southern portions of the county, we find the St. Louis Limestone as the surface rock, and it is over this area that the best farming land is located. This is the massive cavernous limestone in which Mammoth Cave and other smaller caverns of that region were formed.

Over the central, western and part of the northern portions, the members of the Chester Group are exposed and

capped by the first members of the Coal Measures, the base of which is the Conglomerate Sandstone.

In the northwestern portions the higher members of the Coal Measures appear, and with them the coals. The first of these coals has been found of workable thickness at places.

Over the area of St. Louis Limestone exposure, there are no clay deposits, with the exception of the red clay resulting from limestone decay.

The survey of the clays of this county has not been completed, but those examined were in the Chester Group; some of them just above the Big Clifty Sandstone; others at the base of the Conglomerate Sandstone. Doubtless, in the continuation of the work, clay deposits will be found at places between the St. Louis Limestone and Big Clifty Sandstone.

Following are reports of the deposits examined:

THE E. P. SANDERS PLACE.—Mr. Sanders lives on the Brownsville and Bowling Green Road, about four miles southeast of Brownsville and two and a half miles east of Green river.

Around the end of a bold ridge across the southern part of his farm, the surface shows numerous pieces of kaolin made almost black by the percentage of manganese oxide. On the steep slope these pieces show along a belt about ten feet wide. A shallow pit was dug into the material, but no definite deposit was located here. The soil is very dark and thickly set with pieces from one to six inches in diameter. A luxuriant plant growth testifies as to the fertility of this soil.

The following is the section here:

1. Eroded Conglomerate on hill.
2. Covered ..... 30 ft.
3. Dark soil, with manganese and kaolin..... 5 ft.
4. Covered ..... 10 ft.
5. Gray Limestone of Chester Group..... 7 ft.

THE JOHN WELLS PLACE.—This farm is on the Brownsville and Bowling Green Road, three miles southeast of Brownsville. At this place there is a thin stratum of coal underlaid by dark clay which occur in the Chester Group near the top. This is a

very persistent coal and clay; the two are exposed at numerous places over the county.

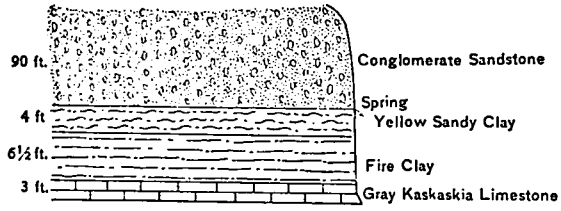
A typical exposure at this coal is shown in the following section, reading downward:

1. White sandstone	20 ft.
2. Brown, grained limestone	5 ft.
3. Dark shale	6 in.
4. "Dark, shaly clay"	2 ft.
5. Coal	1 in.
6. Dark, shaly clay	3 ft.
7. Covered	10 ft.
8. Sandstone	20 ft.

This material is on the order of a clayey shale and to some extent resembles a fire-clay. It contains a vast amount of impurities and is easily fused. The clay is apparently the same above the coal as below.

THE CHARLES B. HAZELIP PLACE.—This place is on a neighborhood road two miles southeast of Brownsville and one mile east of Green river. Near Mr. Hazelip's dwelling is an exposure of clay at the foot of a high Conglomerate cliff.

The following section was made there:



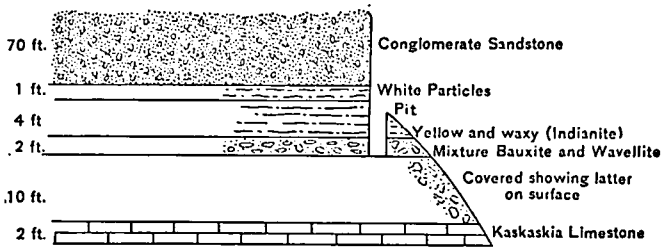
This yellowish clay contains a large and probably injurious amount of sand. The dark clay below is quite free from grit, however, and it is from above this impervious bed that the spring issues. This clay would probably prove valuable for the manufacture of earthenware. A mixture of the two clays would be better than either one taken separately, for the top layer is probably too lean and the lower too fat.

THE JOHN T. B. STICE PLACE.—Mr. Stice's farm is on a small neighborhood road one and a half miles south of Brownsville on the east bank of Green river. At the east side of his farm, one-half a mile from the river, there is an interesting deposit.

Here there is a long hollow with bold ridges on either side. Along these ridges, at the base of Conglomerate cliffs, there are outcroppings or small white pieces of clay. At one point, a pit was dug into this material to the depth of seven feet. Beneath the surface the pieces were more waxy in appearance. Deeper down, the material becomes brown and hard, resembling bauxite.

Analyses have proven this waxy material with a smooth conchoidal fracture and the white particles above it to resemble indianaite, and the material below to be a mixture of bauxite and wavellite. The one changes very gradually into the other.

The following is a section at this exposure:*



This material is stained with iron oxide to some extent on the outside of the pieces. The indianaite is found in pieces from the size of a bird's egg to six inches in diameter. The mixture of bauxite and wavellite occurs in chunks or boulders from six inches to a foot thick.

Following is the analysis by Dr. A. M. Peter, Survey Chemist, of the white material at the top:

	Per cent.
Moisture	5.15
Ignition (combined water and volatile matter)	14.52
Silica	42.40
Alumina	36.21
Ferric oxide	0.45
Lime	0.38
Magnesia	0.53
Potash	0.09
Soda	0.08
Phosphorus pentoxide	0.20
Titanium dioxide, Sulphur trioxide	Traces
Total	100.01

* For "indianite," in the cut, read "indianaite."—C. J. N.

The following is the analysis of the waxy material:

	Per cent.
Moisture	6.84
Ignition (combined water and volatile matter)	13.84
Silica	42.42
Alumina	35.20
Ferric oxide	0.64
Lime	0.34
Magnesia	0.53
Potash	0.23
Soda	0.09
Phosphorus pentoxide	0.22
Titanium dioxide, Sulphur trioxide	Traces
Total	100.35

Following are Dr. Peter's comments: "This has substantially the same composition as the white material of the first analysis. The analyses are close to those of the indianaite of E. T. Cox."

An analysis of the hard brownish material at the bottom is as follows:

	Per cent.
Moisture	13.65
Ignition (combined water and volatile matter)	20.92
Silica	20.04
Alumina	40.53
Ferric oxide	1.24
Lime	0.36
Magnesia	0.40
Potash	0.31
Soda	None
Phosphorus pentoxide	3.75
Titanium dioxide	A trace
Sulphur trioxide	0.27
Total	101.47

Dr. Peter comments on the material as follows: "Possibly a mixture of bauxite and wavellite. The material is interesting and deserves further study."

THE W. B. PARSLEY PLACE.—This place is about five miles northeast of Brownsville and three miles from the mouth of Nolin river.

On this place there is a deposit of clay exposed by a ditch about fifty yards long. This ditch was made in search of asphalt rock, but not dug to sufficient depth to expose anything but soil and clay.

The following is a section here:

1. Soil	3 ft.
2. Light colored plastic clay	3½ ft.
3. Covered	10 ft.
4. Chester Sandstone (bituminous)	4 ft.

In this sandstone exposure there are signs of asphalt, but considerable work is necessary to show whether or not it is present in paying quantity.

An analysis of the clay, by Dr. A. M. Peter, Survey Chemist, is as follows:

	Per cent.
Moisture	1.79
Ignition (combined water and volatile matter)	6.36
Silica	64.36
Alumina	20.90
Ferric oxide	1.39
Lime	0.40
Magnesia	0.69
Potash	1.88
Soda	0.17
Titanium dioxide	1.32
Phosphorus pentoxide	0.06
Sulphur trioxide	Trace
Total	99.32

Remarks by the Chemist: "This clay should be quite refractory, and, being quite sandy, should shrink very little in burning."

The Larue-Taylor Field.

This territory, which, comparatively speaking, is of small area, lies along the boundary of Larue and Taylor counties, in the neighborhood around Hibernia postoffice. Hibernia is located on the boundary line of the two counties, about fourteen miles east of Buffalo, in Larue county, and about nineteen miles northwest of Campbellsville, the county seat of Taylor county. The boundary line of the two counties, at this point, follows the crest of a prominent ridge running in a northeast-southwest direction. Along this ridge runs what is familiarly known as "the ridge road" from Buffalo to Campbellsville. This ridge, at the locality under discussion, is capped by the weathered remains of the Conglomerate Sandstone. The clay exposures of the neighborhood, worthy of notice, occur at the base of this formation, occupying the same relative position as the kaolin deposits of Hart county.

Although the district is one of limited extent, the clay occurs in deposits of considerable quantity, both vertically and horizontally, and, everything considered, the field offers some good propositions. It bids fair to usher developments into the section such as will be of material value to the immediate neighborhood and a credit to the State. At present, the most available point of railway transportation is Hodgenville, the county seat of Larue county, a distance of about sixteen miles, on a branch of the Illinois Central Railroad. Campbellsville, on a branch of the Louisville & Nashville railroad, is about an equal distance from the most easterly exposure of the field, but is reached by a much rougher wagon-way.

There are no exposures of Chester Sandstone nor Chester shale in this part of the State. The Conglomerate Sandstone has, apparently, been superimposed directly upon the limestones, shales, and cherts of the St. Louis Group.

The kaolins of the district are related to this prominent unconformity between the Subcarboniferous series and the basal formation of the Coal Measures. In just what way the deposition was brought about is yet a question. The clay occurs in bedded deposits exposed around ridges and hills at practically the same elevation at all points. The writer has advanced and

supported the theory that these deposits were laid down in an inland sea or lake, previous to the deposition of the Conglomerate Sandstone; that they are younger than the formations on which they rest and older than the Conglomerate according to the law of direct superposition of strata. If this be the case, then the deposits are continuous as horizontal, lense-like beds entirely through the hills and ridges, in a similar way as occur the deposits of the Mississippi embayment region of the State, in the counties of the Jackson's Purchase, or as the fire-clay deposits of Carter county. The latter clays occupy the same geological position as the kaolins of the Hart, Taylor and Larue fields, and have been proven to occur in horizontal beds in a similar manner as coal seams or as other under-clays. This theory of occurrence has never been tested for the kaolins of the district under discussion, because of the lack of developments in the clay-mining industry on the one hand, and on the other hand the lack of proper boring or drilling equipments on the part of the State Geological Survey.

If the theory does not prove valid, then the clays perhaps occur only as rim deposits, having been laid down as flanking beds of marine or fluviatile origin, or else collected as residues by the leaching action of water passing down through the porous Conglomerate Sandstone and following horizontally to the surface along a more impervious stratum at the base. Not a great deal of tunneling or drilling will be necessary to prove the real character of the beds and consequently the mode of origin.

In the Larue-Taylor field there are deposits of clay of various shades of color and degrees of purity which are known to be plastic clays of residual origin. These deposits are entirely a different proposition from the kaolins, however, and will be discussed under a different subject-head.

The Kaolin Exposures.

The Thomas J. Hash Property.—This property is in Taylor county, but borders on the Larue county boundary to the north. Mr. Hash is the owner of a small store on the boundary line, at which is located the post-office known as Hibernia. On land owned by Mr. Hash, at a point about one hundred and

fifty yards south of his store and dwelling, there is an exposure of excellent clay. This exposure is along a spring branch which flows out at the base of the Conglomerate Sandstone. The question naturally arises, Is the spring a result of the clay deposit which the water encounters on passing down through the Conglomerate, or is the clay deposit a result of deposition by the spring? The former seems to be the true condition. In the first place, if the deposit were formed by the spring branch, one would expect the bed to contain alternating layers of gravel and sand from top to bottom. As a matter of fact, borings show that sand and gravel occur only at the surface. The surface sand and gravel form the spring bed resting on the clay deposit at this point. This gravel is a result of concentration of pebbles from decay of the Conglomerate Sandstone; the sand cementing the pebbles is broken loose by continued exposure to atmospheric agencies and washed away, leaving the quartz pebbles quite thickly scattered over the surface. At places this gravel has been accumulated to a considerable amount and may be easily mistaken for old river deposits.

Again, that the clay is not residual from spring water is shown by the fact that clay is found at the same elevation across a ravine to the east and also on the opposite side of the ridge on property belonging to Mr. T. J. Nelson. This ridge runs to a height of from seventy-five to one hundred and twenty feet above the clay level. These latter exposures are in no way related to the spring branch mentioned above.

At the first mentioned exposure along the branch, work with a post-hole digger and auger revealed the following section:

	Ft.	In.
1. Bluish sand and gravel	2	0
2. Brownish clay	3 in. to	4
3. Very white clay		10
4. White clay, slightly stained yellow	11	0
5. Bottom of boring.		

The quantitative analysis of layer No. 3, as made by Burk and Lyon, follows:

	Per cent.
Hygroscopic water	3.82
Combined water	12.10
Silica	49.14
Alumina	32.24
Iron oxide (Fe_2O_3)	1.40
Lime	0.61
Magnesia	0.09
Sulphur trioxide	0.24
Alkalies	1.26
Titanium dioxide	0.01
Total	100.91

The rational analysis of the above clay, made by Burk and Lyon, follows:

	Per cent.
Clay substance	82.75
Quartz	16.06
Feldspathic detritus	1.19
	100.00

The quantitative analysis of layer No. 4, made by Burk and Lyon, follows:

	Per cent.
Hygroscopic water	2.71
Combined water	15.66
Silica	43.64
Alumina	34.57
Iron oxide (Fe_2O_3)	2.01
Lime	0.99
Magnesia	0.10
Sulphur trioxide	0.53
Alkalies	0.81
Titanium dioxide	Trace
Total	101.02

Following is the rational analysis of above clay, also made by Burk and Lyon:

	Per cent.
Clay substance	93.67
Quartz	5.19
Feldspathic detritus	1.14
	100.00

In layer No. 4, there are occasional hard white particles of clay which on slight notice may be taken for gravel. They may be scratched with the finger-nail, however, and would possibly be of no serious detriment to the clay proper. These particles are due no doubt to a different percentage of combined water in their make-up.

THE J. H. DESPAIN PROPERTY, No. 1.—Along the same ridge as described above, one quarter of a mile to the south, a similar clay occurs on property belonging to Mr. J. H. Despain. Borings were made at the same elevation as the deposit on the Hash property. Clay was encountered at a depth of six and one-half feet. The clay at this point was penetrated to a depth of three and one-half feet, this being the limit of practical boring with the clay auger used. The clay is of very smooth texture, free from physical impurities, such as sand and gravel, and, although considerably stained with iron oxide, etc., it is likely the percentage of coloring matter is quite small.

The following section was proven for this point:

1. Dark humus soil..... 3 ft.
2. Bluish "quicksand"..... 3½ ft.
3. Yellowish-brown clay..... 3½ ft.
4. Bottom of boring.

THE T. J. NELSON PROPERTY.—This property is on the opposite or west side of the ridge from the Hash property previously described. There is no visible or open exposure on this place, but the clay auger proved the presence of a nice white grade of kaolin at practically the same elevation as on the east side of the ridge. At this point, along a gentle ravine, there is a small level area of dove-tail shape about twenty feet across. This area appears to have been formed by surface water encountering the clay deposit as it flows down the ravine; the clay being not easily eroded because of its impervious nature, the abrupt bench-like area has resulted. The clay is concealed by about four and a half feet of very fine-grained sand, commonly called "quicksand."

The following is a section here as made with auger:

1. Dark "quicksand"..... 4½ ft.
2. White clay, slightly stained..... 3½ ft.
3. Bottom of boring.

THE JOHN HEADSPETH PROPERTY.—This farm is about three miles southeast of Hibernia. Mr. Headspeth lives about one mile and a half a little south of east from Poplar Grove church.

On this property, two hundred yards southeast of Mr. Headspeth's dwelling, there is an exposure of white clay which shows along the sides of a small spring branch; this branch forms one of the heads of Black Snake creek. About four feet of the deposit is exposed. The upper portion of the clay is stained yellow by waters flowing from the ferruginous Conglomerate Sandstone above.

The clay auger was used in prospecting the deposit, giving the following section:

1. Soil and roots	1 ft.
2. Yellowish clay	2 ft.
3. White clay, slightly stained	8½ ft.
4. Bluish clay	3 in.
5. Bottom of boring.	

This clay, like the deposit on the property of Mr. Thomas J. Hash, contains occasional particles of clay which are much harder than the clay proper. These particles are with some difficulty scratched with the finger-nail and break with a distinct conchoidal fracture. The clay would possibly need to pass through a disintegrator in order to eliminate the hard particles. Otherwise the clay is of an excellent texture; the deposit covers a considerable area and offers a splendid proposition. The Headspeth property is bounded on the north by that of Mr. William Hall, on the east by that of the Webster heirs, on the south by that of Mrs. Bettie Matherly, and on the west by that of Mr. William Warren.

OTHER CLAYS OF THE DISTRICT.

THE SKAGGS-UNDERWOOD PROPERTY.—This clay exposure is along the boundary line of property belonging to Mrs. Martha J. Underwood on the east, and Mr. John C. Skaggs on the west. The point of exposure is in Larue county, about one-half mile northeast of Hibernia, Ky.

This clay is of residual origin at the top of the St. Louis Limestone. The exposure is along a prominent gully and the thickness measures something like seven and one-half feet. It

may be that the thickness, as shown by actual measurements with hand-level, is somewhat exaggerated by redeposition along down the stream way. The deposit contains clay of many colors; marked shades of yellow, red, drab and gray, mixed in thin alternating layers.

The following is a section here, taken down the sides and along up the gully:

	Ft.	In.
1. Soil	2	6
2. Gravel		11
3. Mixed colored clay	7	6

An interesting feature of this deposit is the amorphous silica contained in the clay. Throughout the deposit there are occasional concretions or blotches of white silica; this material is in every state of solidity from smooth, white powder to round and cylindrical concretions of white chert. It may be that these concretions are due, in some way, to an over amount of silica in the make-up of the clay deposit. The presence of silicious concretions in clays and shales offers an interesting field for chemical investigation.

THE J. H. DESPAIN PROPERTY, NO. 2.—The kaolin exposed on property belonging to Mr. Despain has already been described. About one-quarter of a mile further south or one-quarter of a mile south of Hibernia, there is another deposit of dark shaly clay with layers of red clay near the base. This clay-shale is near the top of the St. Louis Group and shows a thickness of about twenty-two and a half feet in a large gully, as given below:

Dark, shaly clay	15 ft.
Dark and red, alternating	2½ ft.
Grayish clay	5 ft.

THE JOHN BULAY PROPERTY.—This property is on what is known as the ridge road from Buffalo to Campbellsville, about one mile a little east of north from Badger. The property is in Larue county.

About two hundred yards south of Mr. Bulay's dwelling there is an exposure of ochreous clay on a bold hillside near the top of the St. Louis Limestone. There is no Conglomerate exposed here. The thickness at this point is not known, but

is apparently from three to eight feet. The clay is of a brilliant yellow color and may prove valuable in the manufacture of paint.

About an equal distance west of Mr. Bulay's dwelling there is an exposure of clay at the same elevation, showing a thickness of eight feet. At this point the clay is a mixture of yellow and gray in thin alternating layers.

THE PERKINS-DOBSON PROPERTY.—This property is near the Hart and Green county line about one mile east of Powder Mills. Here there is a large pond, or marshy lake, covering fourteen acres area and underlaid by a drab colored, plastic clay. This pond is about one mile south of the Greensburg and Munfordville road. The pond is at the top of the St. Louis Group and is held by the compact, impervious clay below. In wet or rainy seasons the pond overflows into a branch of Lynn Camp creek. A clay auger was sunk at the side of the pond to a depth of nine and a half feet into the clay without penetrating the entire thickness of the deposit.

The pond could be drained by a shallow ditch; in fact, it was so drained at one time and the area cultivated. The water at present is about three feet deep, while a ditch four feet deep would carry the water out into Lynn Camp creek, only a short distance away.

The clay is very "fat," free from grit, and might be used in the manufacture of brick, tile, or earthenware. There are some excellent exposures of oolitic limestone in the neighborhood, and should this clay, by analysis, prove suitable, a Portland cement proposition might be presented. The Geological Survey will take this matter up at a later date.

Grayson County.

The geology of Grayson county is somewhat similar to that of Edmonson, and since only a small portion of the county, next to the Hardin and Hart lines, was surveyed for clays in connection with this report, only a brief mention of the geology of that portion is necessary.

Over the northeastern and eastern portions of the county the low lands show exposures of St. Louis Limestone. The uplands show the Big Clifty Sandstone and other sandstones, limestones and shales of the Chester Group, while the higher hills are capped with Conglomerate Sandstone.

The Big Clifty Sandstone is very precipitous and shows some excellent exposures and picturesque scenery in this region. It was from the high cliffs along Big Clifty creek that this formation was named by Prof. C. J. Norwood in his report on the region along the Louisville, Paducah & Southwestern Railroad,* now the Illinois Central Railroad.

The following places were examined in Grayson county:

THE GARTEN PETTY PLACE.—Mr. Petty's farm is just west of the I. C. R. R., one-half mile north of Big Clifty. About one hundred yards west of the railroad, on the southern part of the farm, there is a small spring which issues above a deposit of impure, plastic clay. The exposure is very slight in its vertical extent, but shows at various places around a large hill.

The following is the section here:

1. Brown sandstone..... 25 ft.
2. Drab, plastic clay..... 3½ ft.
3. Gray limestone..... 10 ft.
4. Big clifty sandstone (covered).

This clay does not present a favorable appearance, being a mixture of clay, soil and organic matter near the top. This clay might be used, however, for low grade earthenware, etc.

THE CHARLES LOVE PLACE.—The farm of Mr. Charles Love is on the Summit and Rock Creek Road two and a half miles east of Big Clifty. On this farm there are numerous large gullies at the top of the Big Clifty Sandstone, and at one point there are several exposures of a dark, non-plastic clay deposit. No plastic clay nor coal is associated with this deposit.

We get the following section at this place:

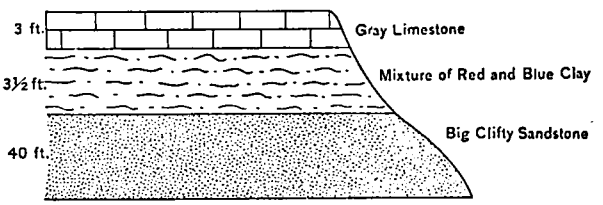
1. Soil and pebbles..... 5 ft.
2. Dark, non-plastic clay..... 8 ft.
3. Big Clifty Sandstone..... 30 ft.

*Geology of the Region Adjacent to the Louisville, Paducah & Southwestern Railroad. Kentucky Geological Survey, Vol. I., N. S., 1875; p. 369.

The horizontal extent of this deposit is not so great as some of the plastic clay deposits. It is exposed over an area of two acres or more, however.

THE JAMES MATTINGLY PLACE.—This place is on the Summit and Rock Creek Road, about three and a half miles east of Big Clifty. There is a deposit of red and bluish clay here about three and a half feet thick, which is exposed in numerous ditches at the top of the Big Clifty Sandstone just above a stratum of Kaskaskia limestone.

Here the following section was taken:



This clay is very lean. It is little plastic except in small state of division. It is quite heavy, and the two colors alternate in thin layers. This material might be more appropriately called an argillaceous shale. Its relation to the formations is inverted from that of the plastic clays at most places—a limestone above and sandstone below, instead of a limestone below and a sandstone above.

CHAPTER II.

Clays of the Red River Valley.

The following account of some of the clays of the Red River Valley is necessarily no more than a general outline of the clay resources of the valley. Limitations as to time and means at the command of the Survey rendered it impossible to cover the ground with any degree of completeness, and this preliminary statement is given because it was desired to incorporate all the data that could be gathered within the time in a general bulletin to be issued at an early date. The field is an extensive and promising one, and it is hoped that the Survey may be permitted to continue the work and issue a more complete report hereafter.

The Red river has its origin in eastern Wolfe county, from the union of small mountain streams, some of which have their initial flow in adjoining counties. It traverses Wolfe county from east to west, flows along the southern border of Menefee, across Powell, forms the boundary between Clark and Estill, and empties into the Kentucky river at the corner of Clark, Estill and Madison counties. In this distance it crosses several formations, extending from upper beds of the Coal Measures down to and including upper members of the Cincinnatian division of the Ordovician. At many places along its course the banks are shallow and gently recede to bottom lands. Toward the western corner of Wolfe and Menefee counties, where it has cut through the massive Conglomerate Sandstone, and near its mouth above the Kentucky, its banks are precipitous and the valley narrow.

In dealing with the clays of the Red River Valley, reports were made not merely of clay deposits geologically related to Red river, but all deposits with which the writer, by search and inquiry, came in contact. Some of the fire clay deposits, for instance, seem to follow along the basal formations of the Coal Measures at almost right angles to the river. Others of the deposits are residual from shales, etc. But many of the

valuable plastic clay deposits are the result of redeposited materials from the Coal Measures.

Every river possesses three important agencies: erosion, transportation, and deposit. So it is true that many of the clay deposits along Red river have been formed from clay materials which, originally present in the shales and argillaceous formations of the Coal Measures and possibly the shales lower in the series, have been eroded, carried down and subsequently deposited. This is noticeably true of the loam deposits around Stanton, in Powell county.

Along Lulbegrud creek, in Clark county, around Indian Fields, there are a number of deposits of greenish, plastic clay. These deposits have originated from the upper beds of the Crab Orchard (Niagaran) Shale.* They are evidently residual in character and follow along the area of Niagara exposure. The Niagara or Crab Orchard Shale where exposed to weathering agencies becomes friable and breaks up into minute greenish flakes. These particles ultimately slake under the influence of rains and are carried down into the low lands where they build up quite extensive deposits of greenish, plastic clay. A great quantity, however, of this disintegrated material is carried into the minor streams and borne away to the large rivers, where it becomes mixed with fine sand and at some point of quietude is reprecipitated or in part carried on into the sea.

Following are the clay deposits examined:

THE MORGAN EUBANK PLACE.—Mr. Eubank's farm is on the Indian Fields and Irvine Road, four miles south of Indian Fields, Clark county, Ky.

On this place and the one adjacent on the west belonging to Mr. D. J. Snowdon, there is quite an extensive deposit of greenish, plastic clay. By hand-level measurements of the deposit as exposed along large gullies, the thickness averages about twenty-one and a half feet. It is found at various points of exposure over an area of perhaps one hundred acres. This is a Niagaran deposit and it is quite likely that back some distance into the hills, as would be revealed by tunneling, the material would become shaly in character.

* See table of Formations, page 14.

Following is a section of the deposit as exposed along gullies:

1. Dark, brown limestone	4	ft.
2. Greenish, plastic clay	5½	ft.
3. More compact laminated clay	6	ft.
4. Drab clay, very fat	10	ft.

This deposit belongs, doubtless, to what Prof. Foerste calls the Estill Clay of the Crab Orchard Division of the Silurian Series.

THE W. T. STANHOPE PLACE.—This farm is on the Indian Fields and Irvine Road, two miles south of Indian Fields, Clark county, Ky.

West of Mr. Stanhope's dwelling a hundred yards or more, there is an exposure of brown, plastic clay from ten to eighteen feet thick. This clay is to be found over three or four acres of ground and is a common clay in this neighborhood. It was not thought necessary to report more than the one place of this variety because of its impure nature. It would probably make a nice brick, however.

The deposit is at the bottom of the Ohio Black Shale and is probably residual from the shale, having been mixed with iron oxide enough to give it the brown color. Small particles of shale and mica are visible with an ordinary lens.

Following is the section here:

1. Dark Ohio Shale	40	ft.
2. Brown, plastic clay	15	ft.
3. Covered.		

THE M. H. HISLE AND A. B. HAMPTON DEPOSIT.—This deposit of greenish, plastic clay occurs on both sides of the Indian Fields and Irvine Road, one quarter of a mile south of Indian Fields, Clark county, Ky. The east side on Mr. A. B. Hampton; on the west, Mr. M. H. Hisle.

This deposit has an average thickness of about sixteen feet and appears to be a clay of excellent quality. It ought to make vitrified tile and brick. The deposit appears to be very uniform throughout its vertical and horizontal extent. It is found exposed over several acres of territory. The soil above it is excellent for agricultural purposes, especially hay.

The following is a section here, as shown by auger borings:

1. Soil	2½ ft.
2. Greenish, plastic clay	16 ft.
3. Limestone	?

This is the Plum Creek Clay.

THE ORLANDO HENSLEY PLACE.—Mr. Hensley lives on the Indian Fields and Pine Ridge Road, about two and a half miles east of Indian Fields, Clark county, Ky. About one-half a mile north of Mr. Hensley's home, on a small spring branch which flows into Lulbegrud creek, there is an exposure of yellow, ochreous clay about four feet thick. The exposure runs fifteen or twenty yards along the branch to its head, which is a chalybeate spring issuing from above the ochreous clay deposit. This clay is covered above by vegetation and hidden by the branch below, but it is evidently Devonian and has resulted from residues from the Ohio Black Shale.

Following is the analysis of this clay, made for the Survey by S. D. Averitt, of the State Agricultural Experiment Station:

Hygroscopic moisture	3.04
Combined water and volatile matter	12.28
Silica	44.40
Alumina	11.35
Ferric oxide	24.69
Lime	0.26
Magnesia	0.38
Potash	1.99
Soda	0.26
Titanium dioxide	0.75
Sulphur trioxide	0.56
Phosphorus pentoxide	0.13
	100.09

Higher up the hills and across a hollow to the north from the above described deposit about one-half a mile, there is a deposit of pinkish, plastic clay about six feet thick. This deposit is at the top of the Devonian or Ohio Black Shale.

The following is a section made at this deposit:

1. Soil	2 ft.
2. Pinkish clay	6 ft.
3. Black Shale	Flat Exposure

THE B. L. BRUNER PLACE.—The clay on this farm is exposed along the Indian Fields and Clay City Road about two miles from Indian Fields, Clark county, Ky. The clay is exposed on both sides of the named road and outcrops on several hillsides around in the immediate vicinity.

It is a greenish, plastic clay resulting from Crab Orchard Shale and shows an average thickness of about four and a half feet. A very luxuriant plant growth on the thin soil above the clay testifies as to plant food contained therein. These Crab Orchard clays, as a rule, contain a noteworthy amount of potash.

The following is a section of this clay as exposed by gullies, eroded hillsides, etc.:

Soil	2 ft.
Greenish, plastic clay	4½+ ft.

THE ROBERT KIDD PLACE.—This land is on the Indian Fields and Mt. Sterling Road three miles north of Indian Fields, Clark county, Ky.

Here the hills over an area of about one hundred and twenty-five acres show exposures of a greenish, plastic clay about ten feet thick as an average. The clay is Crab Orchard in age and occurs immediately below a three-foot stratum of Corniferous Limestone. This clay is a very fat material, free from gravel, sandy grit, etc.

The following is an average section of the exposures around the hillsides:

1. Devonian (Corniferous) Limestone	3 ft.
2. Greenish clay (Silurian)	10 ft.

This clay is very similar in appearance to other Crab Orchard clays which have been recommended for Portland cement.

THE A. H. ANDERSON PLACE.—The clay exposure under consideration is on the Indian Fields and Clay City Road at the crossing of the Virden and Kiddville Road, two miles southeast of Indian Fields, Clark county, Ky., about three hundred yards west of the L. & E. R. R.

Here there is a long gully which exposes the entire deposit of greenish, plastic clay. The deposit is quite an extensive one vertically and is found exposed over an area of from fifty to

seventy-five acres. The clay is Crab Orchard and is interlaid with strata of massive brown limestone. It is well situated for shipping or for being worked on the ground. Lulbegrud creek flows along about thirty feet below the deposit.

Following is a section of the exposure:

	Ft.	In.
1. Soil and vegetation	2	
2. Greenish, plastic clay	10	
3. Brown limestone layer		10
4. Greenish, plastic clay	11	6
5. Brown limestone layer	4	8
6. Greenish, plastic clay	15	
7. Sand from Lulbegrud Creek	Unconformity	

THE KIDDVILLE EXPOSURES.—There is a small wet-weather branch which flows through the west side of Kiddville, crosses the Indian Fields and Kiddville Road and empties into Lulbegrud creek one mile southeast of Kiddville, Clark county, Ky. Along this branch, west of the town, there are exposures of greenish Crab Orchard Clay on Messrs. A. T. and J. H. Pieratt. On Mr. A. T. Pieratt the exposure by lock level measurement shows to be about twenty-one and a half feet thick on both sides of the branch. Similar exposures are found to the south on Mr. J. H. Pieratt and Dr. J. F. Lockhart; to the west on Mr. J. Eubank and Mr. James Peel; to the north on Mrs. Carrie Hardy; to the east, Mr. J. L. Jackson and Mrs. Mary Elliott.

The following is the section as exposed:

1. Soil with grass	2 ft.
2. Greenish, plastic clay	15 ft.
3. Deeper green clay	5½ ft.
4. Covered.	

THE ABNER CLAY PLACE.—The clay on this farm is exposed along the Kiddville and Indian Fields Road, one-half a mile south of Kiddville.

This greenish, plastic clay is a continuation of the deposits at Kiddville as above described and shows exposures on both sides of the named road. The clay extends back under the low, rich meadow lands on either side and ranges from five to fifteen feet in thickness. Toward the top, the clay is impure with grass roots and decayed carbonaceous matter, but deeper

down is a clay of excellent plastic qualities. This clay becomes considerably lighter in both weight and color when dried. It is scarcely necessary to attempt a diagram of these exposures because the thickness is not accurately known. Only surface indications are visible. It is reported, however, as being twenty feet thick at places where wells, etc., have penetrated the deposit.

THE VIRDEN EXPOSURE.—In the first cut east from Virden, on the L. & E. R. R., Powell county, Ky., there is an exposure of Crab Orchard Shale. This shale, where exposed, has weathered to a greenish, plastic clay.

The land on either side of the railroad here is owned by Mr. A. H. Anderson. In the cut there is about four feet of Crab Orchard Shale at the bottom, overlaid by Corniferous Limestone, which is itself overlaid by Ohio Black Shale. This shale and clay are exposed over the lands on both sides of the railroad, covering an area of over one hundred acres. The strata of Corniferous Limestone range from five to nine feet in thickness.

Following is an average section of the exposures here:

1. Ohio Black Shale..... 20 ft.
2. Corniferous Limestone..... 5-9 ft.
3. Greenish shale (Silurian)..... 4-7 ft.
4. Covered.

Following is the analysis of this clayey shale, made for the Survey by S. D. Averitt, of the State Agricultural Experiment Station:

	Per cent.
Hygroscopic moisture	1.99
Combined water and volatile matter	19.26
Silica	37.30
Alumina	15.63
Ferric oxide	2.37 (?)
Lime	10.59
Magnesia	2.22
Potash	3.56
Soda	0.33
Titanium dioxide	0.50
Sulphur trioxide	0.12 (?)
Phosphorus pentoxide	0.26
Iron bisulphide (FeS_2)	4.65 (?)
	98.78

The total sulphur, calculated as SO_3, is 6.31 per cent. Total iron, calculated as FeO_3, is 5.47 per cent. The greater part of the sulphur is in the FeS_2, but some of it is evidently in the form of sulphate.

THE JAMES HENSLEY AND CHAS. SWOPE EXPOSURES.—This deposit of greenish Crab Orchard Clay is exposed north and south of the Indian Fields and Clay City Road, near the boundary line of Clark and Powell counties, two miles west of Virden.

On the north there are exposures ranging from five to nine feet thick on the farm of Mr. James Hensley. On the south, there are exposures on Mr. Charles Swope of a similar character. A well on Mr. Swope's farm is said to have penetrated about fifty feet of this plastic clay. Below the exposures there is a stratum of brown limestone about two feet in thickness.

Following is an average section:

1. Soil, with grass roots..... 2½ ft.
2. Greenish, plastic clay (Silurian).....5 to 9 ft.
3. Brown Limestone..... 2 ft.

THE J. M. KENNON PLACE.—This place is on the Clay City and Hardrick's Creek Road one mile from Clay City, Powell county, Ky.

The clay examined on this farm is in a low, level area which was once covered by Red River. The clay is plainly fluviatile in origin and is of a light brown color. It is reported as a good brick clay, having been used for that purpose by a local company. The exposure presents about three feet of the upper portion of the deposit. The entire thickness is about six feet.

Following is the section of exposure:

1. Sandy soil..... 2 ft.
2. Light, brown clay..... 6 ft.
3. Ohio Black Shale.....Covered

THE EDMUND ROSE PLACE.—The land under consideration is on the Clay City and Stanton Road one mile east of Clay City, Powell county.

The clay deposit here is resting on Ohio Black Shale at the very top. The clay is of a shaly character, bluish in color and

contains a layer of iron oxide near the center. The entire deposit is about fourteen feet thick. At other points around the same elevations over a considerable area, this clay is exposed. The iron layer is very persistent.

Following is a section of average exposure:

1. Shaly, plastic clay	5½	ft.
2. Layer of iron oxide	4	in.
3. Shaly, plastic clay	8	ft.
4. Ohio Black Shale	95	ft.

THE JOHN WASSON PLACE.—The farm of Mr. John Wasson is on the Rosslyn and Cat Creek Road four miles south of Rosslyn, Powell county, Ky.

This vicinity is one of rugged topography and the highest ridges are capped with Conglomerate Sandstone, the basal formation of the Coal Measures.

Around a valley on the flanks of two ridges on the named farm, there are exposures of a fire-clay deposit at the base of this Conglomerate Sandstone. The exact thickness was not determined, only three feet of the deposit being uncovered at any one place, but supposed authorities claim that a prospect pit was once dug through it showing it to be about seven feet thick. The prospect shaft was dug for iron ore. A light, bluish plastic clay, often used as a substitute for whitewash, is common below the fire clay in thin layers. It is eroded and redeposited particles from the fire clay.

Following is a section of the exposure:

1. Soil	2	ft.
2. Fireclay	3+	ft.
3. Covered.		

THE PRICE ARTHER PLACE.—There is an excellent exposure on this place along the Stanton and Rosslyn Road two miles north of Stanton, Powell county, Ky. The clay is grayish in color, tolerably lean in character, and contains some sand in a very fine state of division.

The deposit rests on Ohio Black Shale, but is fluviatile in origin, having been deposited by Red River, which now flows a short distance to the south.

This clay has been successfully manufactured into drain tile, but the local factory at Stanton was closed down for other reasons altogether than the lack of good material. Samples of the tile are in the State Museum on exhibition with samples of the clay.

Following is a section of the exposure on Mr. Arther's place:

1. Soil, with roots..... 1 ft.
2. Gray, plastic clay..... 19 ft.
3. Ohio Black Shale.

The exposure is in the form of a vertical bluff by the roadside.

Following is the analysis of this clay, made for the Survey by S. D. Averitt, of the State Agricultural Experiment Station:

Sample, a light gray clay with many iron stains.

	Per cent.
Moisture	2.30
Combined water and volatile matter	5.78
Silica	63.12
Alumina	18.31
Ferric oxide	3.40
Lime	0.29
Magnesia	0.90
Potash	3.05
Soda	0.89
Titanium dioxide	1.08
Sulphur trioxide	Trace
	99.18

EXPOSURE AT ROSSLYN.—On the south bank of Red River, near Mansfield's Mill, at Rosslyn, Powell county, there is an exposure of about twenty feet of clay. This clay is of a light, gray color, contains a considerable percentage of free silica, and is perhaps a continuation of the deposit described under the head of Price Arther Place, which is about two miles further down the river. The thickness and general sections are the same. The clay at Rosslyn is more loamy in character and some lighter in color, however. See section above on Arther.

JAMES KIRKPATRICK AND OTHERS.—Along the L. & E. Railroad, a few yards west of the station at Stanton, in Powell county, there is an exposure of light-colored, plastic clay similar to the clay on the opposite side of the river exposed on the Price Arther place. The clay here extends back under land belonging to Mr. James Kirkpatrick. Continuing around from left to right in a clock-wise fashion, this clay is exposed on Mrs. Betty Hardwick, Mr. Anthony Norton, Mr. James Ewing and Mr. Albert Welch. From auger borings into this deposit, it proves to range from ten to fifteen feet in thickness, and the area of extension covers perhaps three hundred acres.

The brick for the county court house was manufactured from a portion of this deposit. The bricks are of excellent quality.

Following is a section of the exposure:

1. Soil and sand	2 ft. 8 in.
2. Light colored clay	10 to 15 ft.
3. Ohio Black Shale	Covered

Following is the analysis of the clay, made for the Survey by S. D. Averitt, of the State Agricultural Experiment Station:

Sample, a very light gray clay, with some iron stains; James Kirkpatrick's place, in railroad cut, fifty yards from station at Stanton.

	Per cent.
Moisture	2.04
Combined water and volatile matter	4.47
Silica	70.24
Alumina	15.27
Ferric oxide	2.60
Lime	0.42
Magnesia	0.50
Potash	2.24
Soda	0.90
Titanium dioxide	1.03
Sulphur trioxide	0.05
	99.76

The same deposit occurs eastward on Mr. J. C. Patrick. The clay here contains less silica and shows a very suitable analysis

for Portland cement. Following is an analysis of Mr. J. C. Patrick's clay, analyzed at Ohio State University:

	Per cent.
Water and volatile matter	5.70
Silica	67.30
Alumina	18.22
Ferric oxide	3.08
Magnesia	1.30
Calcium carbonate	1.70
Alkalies	2.70
	100.00

With this clay, Mr. Patrick sent samples of oolitic limestone for the purpose of having them tested for Portland cement. Both materials proved suitable, and good Portland was actually made from a mixture of the two.

Following is the analysis of the limestone. This limestone occurs above Glencairn, in Wolfe county:

	Per cent.
Calcium carbonate	91.40
Silica	4.55
Ferric oxide	1.43
Alumina	2.12
Magnesia	0.80
	100.30

THE JESSE FAULKNER PLACE.—This farm is on the L. & E. R. R., one mile east of Filson Station or Bowen post-office, in Powell county.

About seven feet of the deposit is exposed by a cut along the railroad. It is a dark, plastic clay of fluviatile origin and rests on Waverly shale. The clay is free from gritty particles and is quite strong or fat.

Following is a section of the exposure:

1. Soil	1½ ft.
2. Dark, plastic clay	7 ft.
3. Waverly Shale	Bottom of Cut.

Following is the analysis of this clay, made for the Survey by S. D. Averitt:

Sample, a light brown clay with a good many iron stains. Waverly formation (Linietta ? Clay).

	Per cent.
Moisture	3.46
Combined water and volatile matter	6.36
Silica	64.54
Alumina	19.13
Ferric oxide	0.94
Lime	0.53
Magnesia	0.66
Potash	2.32
Soda	0.51
Titanium dioxide	0.95
Sulphur trioxide	Trace
	99.40

THE W. M. TOWNSEND PLACE.—Mr. Townsend's farm is situated on the Filson Station and Cow Creek Road one mile south of Filson Station, Powell county.

On the above named land there is one very high ridge which rises above the ones in the near vicinity and contains some of the basal formations of the Coal Measures. Near the summit of this ridge there are outcroppings of fire-clay, but the thickness is not known. The indications are that the deposit is of workable thickness, however, being something near six feet thick. There are no good exposures near the deposit, but it is probably just below the Conglomerate Sandstone.

Where pieces of this clay have been exposed on the surface and acted on by atmospheric agencies, they have crumbled to small, angular particles.

Lower down on the ridge, there are layers of a whitish, plastic clay produced by the washing down of the fire-clay elements. No good section can be given.

THE N. FULKS PLACE.—Land belonging to Mr. Fulks lies east and adjacent to the village of Glencairn, Wolfe county.

On the side of a high hill above the first east cut in the Waverly Shale for the L. & E. R. R., there is an exposure of drab, plastic clay. This clay deposit is not in workable quantity, being a product of redeposition from argillaceous shales

and refractory clay above. Above this plastic clay about thirty feet there is a stratum of fire-clay about one and a half feet thick. This is at the junction of the Waverly and St. Louis Limestone.

The following section includes both clays, neither of which are of more than geological interest probably:

1. St. Louis Limestone	40	ft.
2. Refractory clay	1½	ft.
3. Covered	20	ft.
4. Drab, plastic clay	2	ft.
5. Waverly Shale, to bottom of cut	23	ft.

THE O. W. MCNABB PLACE.—Mr. McNabb's farm is situated on the Hazel Green and Mt. Sterling Road, one mile and a half northwest of Hazel Green, Wolfe county. Red river flows along the west side of the farm, leaving a gently sloping valley on the east side. At the outer edge of the valley to the east along the old State Road, designated by the two points above named, there is an exposure of light-colored, plastic clay similar to the Powell county clays, but more nearly white. This clay is plainly fluviatile, having been deposited by Red river before it cut its way a distance of a quarter of a mile westward.

The deposit runs from seven to ten feet in thickness, and is exposed at points over an area of fifty or seventy-five acres.

The clay is free from physical accessories, such as gravel, manganese oxide, etc., but at places contains a considerable percentage of free silica.

Following is a section along the road:

1. Soil	2 ft.
2. Light colored clay	7-10 ft.
3. Shale of Coal Measures	Covered

Following is the analysis of this clay:

No. 2673.—Clay from O. W. McNabb's place, on the Hazel Green and Mt. Sterling Road, one mile north of Hazel Green, Wolfe county. Thickness, 96 inches. A dirty-white, very sandy clay; does not effervesce with hydrochloric acid, and shows no

phosphates. Analysis made for the Survey by S. D. Averitt, assistant chemist in State Agricultural Experiment Station.

Sample air dried.	Per cent.
Moisture	1.16
Ignition (combined water and volatile matter)	3.47
Silica	78.16
Alumina	11.58
Ferric oxide	1.02
Lime	0.32
Magnesia	0.40
Potash	1.85
Soda	0.74
Titanium dioxide	0.88
Sulphur trioxide	Trace
Total	99.58

The analysis was made of unwashed clay, hence the percentage of silica is higher than would be the case with washed clay.

THE F. P. CLARK PLACE.—This land is on the Hazel Green and Mt. Sterling Road, two miles west of Hazel Green, Wolfe county. This clay deposit is possibly a continuation of the one described as the O. W. McNabb Deposit, but somewhat different in character taking it as a whole. The clay is exposed in a large gully along the Mt. Sterling Road, and shows the following section:

	Ft.	In.
1. Soil, with roots	2	0
2. Yellowish, plastic clay	0	1
3. Sandy layer	0	5
4. Dark, plastic clay	0	6
5. Gray, plastic clay	10	0
6. Covered.		

The plastic clay at the bottom is very similar to that described in the section on Mr. McNabb's place.

J. B. KASH AND J. W. STAMPER EXPOSURE.—Mr. Kash's farm is on the Hazel Green and Mt. Sterling Road, one mile west of Hazel Green, Wolfe county.

Mr. Stamper's farm joins Mr. Kash on the west.

On Mr. Stamper's land small, angular particles of flint fire-clay can easily be traced around the high points. These hills are capped with shales of the Coal Measures, and it is near the summit that the fire-clay appears. This deposit was traced east onto Mr. Kash's land, where it is at a much lower elevation because of an anticlinal dip.

No accurate section can be given of this deposit until a prospect pit has been dug into it. Because of the scouting nature of the field work, this was not done by the Survey, but the owner of the property gave assurance that this would be done at their earliest convenience. The outcroppings indicate a deposit of workable thickness.

THE S. W. PERKINS PLACE.—This land is south of the Hazel Green and Mt. Sterling Road, one and a half miles west of Hazel Green, Wolfe county, Ky. Here there is a long, level bottom east and adjacent to Red River. Beneath this low, marshy bottom land there is a bluish plastic clay which becomes much whiter when dried and is probably a valuable clay for brick, tile, sewers, etc. The clay is fluviatile, having been deposited by Red River. It is about six feet thick and shows over an area of about thirty acres. Very thin, damp soil covers the clay, as shown by the following section:

1. Soil ..... ½ ft.
2. Plastic clay..... 6 ft.
3. Shale .....Covered

This clay, mixed with a proper percentage of calcium carbonate, might make an excellent cement.

CHAPTER III.

Clays and Sands of the Jackson's Purchase Region.

The following account of clays and sands of the Jackson's Purchase Region* is, in the main, a compilation and revision of matter taken from Dr. R. H. Loughridge's general report on that district.† With this as one of the purposes in view, a rapid reconnoissance of the region was made during the summer of 1905,—rapid because of the very large area that it was necessary to cover within the short time at command. The objects sought to be accomplished by the field work were to bring the matter from Dr. Loughridge's report up to date as to location and ownership of properties; to gather later data as to established industries; to note such additional exposures of workable clays as could be visited within the allotted time, and to lay the foundation for a systematic, detailed study of the deposits, along economic lines, which is in contemplation with the continuation of the Survey.

The geologic classifications adopted by Dr. Loughridge are used throughout—though it is possible that some minor changes may hereafter prove necessary; and the account of the distribution of the formations is adapted from his report.

Though, for the sake of convenience, quotation marks are seldom used, it is desired that full credit shall be accorded to Dr. Loughridge for all matter for which he is responsible. It is to be understood, therefore, that practically all matter not inclosed by brackets is either adapted from his report, or copied therefrom in full. As a rule, new material, for which the present writer is responsible, is inclosed by brackets.

When analyses taken from Dr. Loughridge's report are used,

*Forms part of the area purchased from the Chickasaw Indians in 1818, through a Commission composed of Gov. Isaac Shelby and Gen. Andrew Jackson. The Indians declined to treat with Gov. Shelby, and Jackson was obliged to conclude the treaty in his own name—whence, "Jackson's Purchase."

†The Geological and Economic Features of the Jackson's Purchase Region, by R. H. Loughridge, Kentucky Geological Survey, 1888.

the old labels are given in quotation, but wherever changes of ownership have occurred, such changes are noted in connection therewith.

TERRITORY EMBRACED.

The territory embraced in "Jackson's Purchase" covers an area of about 2,340 square miles, lying immediately west of the Tennessee river, with the Mississippi and Ohio bordering it on the west and north respectively. It includes Hickman, Calloway, Graves, McCracken, Marshall, Ballard, Fulton, and Carlisle counties, named in the order of their organization, Carlisle having been formed from the southern half of Ballard in 1886.

TRANSPORTATION FACILITIES.

The three rivers that form three sides of the Purchase region afford regular transportation facilities for the contiguous country at all seasons of the year, unless blocked with ice during the winter. The smaller streams in the interior are not navigable.

Several railroad lines traverse the region. The Illinois Central system has two lines: One, connecting Paducah with Louisville (formerly known as the Chesapeake, Ohio & Southwestern), runs southwestwardly from Paducah via Mayfield (Graves county) and Fulton (Fulton county) to Memphis and the southwest; the other, reaching to Chicago on the north and to New Orleans on the south, enters from Cairo, passes through Wickliffe (Ballard county), Bardwell (Carlisle county), Clinton (Hickman county), Fulton (Fulton county), and thence south. The Mobile & Ohio enters from Cairo, passes through Wickliffe, the western portions of Carlisle and Hickman counties, down through Fulton county, and thence to Mobile; a branch two miles long extends from South Columbus to Columbus, and connects with the St. Louis & Iron Mountain Railroad. A line of the Nashville, Chattanooga & St. Louis connects Hickman (Fulton county), with the M. & O. at Union City, and with the I. C. at Paducah Junction; these and other connections made farther south, give Hickman transportation by rail to St. Louis, Chicago, Paducah, Louisville, Memphis, New Orleans, Nashville, etc. Another line of the Nashville, Chatta-

nooga & St. Louis extends from Paducah southward through Benton (Marshall county) and Murray (Calloway county). Another railroad, to cross the region east and west on a line from Columbus through Mayfield, is projected.

Geologic Features.

The Purchase region occupies an interesting geologic position almost at the extreme northern extension of what was once a bay or arm of the ocean, reaching northward from the extreme south, and whose waters washed the Paleozoic shores on the east and west. The northern shore line of the embayment extended across the southern part of Illinois, beginning below the mouth of the Cumberland, at New Liberty on the east, and reaching southwestward parallel with the Ohio river and but a few miles from it, until at a point about fifteen miles north of Paducah it turned sharply westward to within fifteen miles of the Mississippi, when it bent southwest to the river at Santa Fe, opposite Commerce on the Missouri shore. The Tennessee river marks what was then the eastern side of the embayment, while on the west the shore line was twenty or thirty miles beyond the present position of the Mississippi.

Within the region the following geologic formations have been observed.* They are given in the order of position, beginning with the more recent or topmost:

Alluvium (of river and creek bottoms).

Quaternary.

Brown loam; surface loams of the uplands.

Loess; gray silt of Mississippi bluffs.

Port Hudson (Hilgard's Louisiana); stiff dark and bluish clays with calcareous concretions, under the river alluvium, and overlaid in the Ohio Valley by micaceous loam.

Stratified Drift:† rounded chert and quartz gravel interstratified with coarse sand, the whole more or less stained and cemented with iron oxide.

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* Dr. Loughridge noted "a region or belt of massive quartzose sandrocks" which he at first provisionally referred to Devonian age (pp. 18 and 22 of his report), but which he subsequently, from data obtained by boring at Paducah, deemed "in reality the remnants of Chester sandstone" (p. 325 of his report).

† Lafayette formation.—J. H. G.

TERTIARY.

Lagrange (of Safford's Tennessee); stiff plastic clays, variegated in color and interstratified with whitish sand, and holding impressions of leaves.

Lignitic; blackish arenaceous clay and clay-stone, with leaf impressions and beds of lignite and lignitic peat.

Porter's Creek (of Safford's Tennessee); massive and jointed clays (locally called "soapstone"), somewhat micaceous, blackish when wet, dark gray when dry.

Hickman (provisional, of the Hickman bluff); silicious clay-stone over a thick bed of buff-colored clays.

CRETACEOUS.

Ripley; black clay in very thin laminae, separated by fine white and highly micaceous sand; beds of sharp angular white and yellow micaceous sand, 100 feet thick.

SUBCARBONIFEROUS.

Lower (or *Silicious,* of Safford's Tennessee); heavy limestone beds intercalated with dark flint layers.

Next to the soils and timbers, the material of greatest economic importance occurring naturally in the counties of the Purchase region is found in the extensive deposits of clay, in beds of varying thicknesses and characters. While they underlie the greater part of the country, it is only in the hillside ravines, and in the bluffs bordering the streams, that their exposures can be seen.

These clays are derived from the decomposition of the argillaceous shales and rocks of formations older than those with which they are found, and have been transported to this basin from distant localities, by rivers or other currents, and meeting here the quiet waters of what was then an arm of the sea, were allowed to settle to the bottom, gradually filling up the basin. The shallow nature of the basin is shown in the black clays, which are chiefly colored with organic or vegetable decay, and in the beds of lignite and the decayed leaves in the clays.

The decomposition of these dark clays seems to have been followed by a sinking of the region, producing river currents, which swept away the beds in the central part of the region, north to south; again followed by a season, or alternating seasons, of rest and disturbance, during which beds of white clays and of sand were deposited. Such seems to be, in brief, the

history of the deposition of these beds during the Cretaceous, Tertiary and early Quaternary times, after which the heavy deposits of gravel and loam were made, which now cover the entire region.

[The majority of the white clay deposits of economic value are in the Lagrange division of the Tertiary.]

CHARACTER OF THE PURCHASE CLAYS.

In order to more fully test the value of these clays for the finer qualities of ware, arrangements were made (by Dr. Loughridge) with the Rookwood Pottery, of Cincinnati, by which their adaptability for decorated wares was ascertained.* Average specimens from the most important beds were shipped to the pottery, and the results obtained are incorporated with the report on the respective beds, in the following pages.

The clays are divided into three classes—*refractory, unrefractory* and *ochreous.* The former are especially suited to the manufacture of fire-brick and similar articles, whose chief property is resistance to the effects of a high heat. Those of the second class fuse to a greater or less extent in a high heat, and are more suitable to various forms of pottery, etc.

The following is an extract from a letter regarding these clays written by Dr. Karl Langenbeck.† Speaking in regard to the establishment of a pottery for making regular tableware, cups, saucers, plates, bowls, pitchers, etc., he says: "I think it would be a very paying thing, because you have raw material equal to the finest in England, the articles have a constant and ready sale, and are subject to heavy freight rates in transportation from New York, Trenton, or East Liverpool, so that they should be produced near a market, and Kentucky is known as a good market. The practical experiences I have had with the clay from Russell's, near Murray, and with other

* Various wares, including decorated, were also made of some of the Purchase clays, under the direction of Prof. C. J. Norwood, for the Kentucky mineral exhibit at the St. Louis World's Fair, 1904. The work was done at East Liverpool, and only the natural clay (unmixed with any other) was used. On the latter account, especially, the beauty and perfection of the wares attracted the admiration of and elicited praise from clay-workers who visited the exhibit. A gold medal was awarded the clay exhibit. The wares made by the Rookwood Pottery, mentioned above, and most of those exhibited at St. Louis may be seen in the State Geological Museum, at Lexington.

† At the time, connected with the Factory of Decorative Art, etc., at Cincinnati.

clays of the district, have taught me their peculiarities, and I can freely say that, from their great plasticity, they are most easily and cheaply worked, and, from their binding qualities, entail less loss in the kiln than any others I have met with. The Russell clay, with the addition of some flint, makes a very beautiful ivory-ware, almost exactly resembling that made by the celebrated firm of Copeland & Sons, England, for table and toilet sets."

Refractory Clays.

The majority of the clays of this part of the State have been found to be highly refractory when tested before the blowpipe, though many of them contain high percentages of iron and potash, on which their fusibility depends. They vary in color from nearly white to black, and are more or less sandy in their character. They are found in all the counties, in beds varying from two to many feet in thickness. Samples from many of these localities have been analyzed, and the results are given below, preceded by a description of each bed. For convenience, the clays are divided into the following groups: *Drab Clays of the Hickman Bluffs; Silicious Clays of the Columbus Bluffs;* the *White or Light-Colored Plastic Clays;* and the *Black or Dark Bluish-Black Clays.*

A. Clays of the Hickman Bluffs, Fulton County.—The bluffs rise about 180 feet above that portion of the town lying on the river bank, and, as shown in the section on a preceding page, comprise sixty-five feet of loam and silt, and eleven feet of sand and gravel above the clays. The succeeding beds downward comprise clays, clay-stones, and joint clays, varying from each other somewhat in composition and in their refractory character. In the following table of analyses, these beds are placed and described in descending order, the first two numbers being of specimens taken from the bed immediately underlying the gravel, but one-fourth of a mile apart:

No. 2137. *Greenish, sometimes bluish, sandy refractory joint clay,* taken from beneath the gravel bed, one-fourth of a mile north of Hickman, Fulton county. The clay is quite plastic, burns hard, and of a light greyish-buff tint. Before the

blow-pipe it fuses with great difficulty. The bed is several feet thick.

No. 2136. *Greenish, sometimes bluish, sandy refractory joint clay*, taken from beneath the gravel bed in the bluffs in the upper part of Hickman, Fulton county. The dried clay is of a light grey tint, colored in parts of buff and ferruginous. It is moderately plastic, and does not calcine very hard, acquiring a handsome light brick color. It is refractory before the blow-pipe. The clay crumbles easily, and has a thickness of about six feet.

No. 2139. *Soft crumbling clay-stone, refractory, greyish, and somewhat sandy*, forming a ledge under the preceding about two feet thick. It is somewhat ochreous and quite plastic. It burns hard, of a light grey-buff tint, and before the blow-pipe it fuses with difficulty.

No. 2140. *Slate-colored or bluish refractory joint clay*, from the Hickman bluff, and underlying the preceding. It is lilac-grey when dried, somewhat ochreous, quite plastic, and burns quite hard to a light brownish tint. It is quite refractory before the blow-pipe. The bed is several feet thick.

No. 2138. *Greenish clay-stone and green refractory clay*, from Hickman bluff and underlying the preceding. It is banded with yellow ferruginous lines, crumbles easily, and in places is quite solid. The dried clay is light grey in color. It is quite plastic, calcines to a light brick color, and is quite refractory before the blow-pipe. The bed is about ten feet thick.

No. 2141. *Greenish indurated and refractory joint clay*, from the Hickman bluff, and separated from the preceding No. 2138 by eight feet of massive slate-colored clay-stone, having a jointed structure, and in places holding masses of dark opal. The clay on drying assumes a light olive-grey color. It calcines quite hard to a brownish-buff color, and is quite refractory before the blow-pipe. The bed is at least fifty feet thick, passing below the level of the alluvial plain. This clay has not been found elsewhere within the Purchase counties than along the bluffs southward to the Tennessee line.

No. 2135. *Greenish refractory clay*, from the bluffs at Hickman, ninety-five feet above low water. This is the same bed as that of No. 2141. The dried clay is of a light grey tint, considerably mottled with light brownish ochreous material. It

is quite plastic with water, calcines to a reddish-buff color, and is refractory before the blow-pipe, but sintered somewhat.

No. 2334. *Indurated clay from bluff at Hickman,* forty-five feet above low water. This is also of the greenish clay-bed No. 2141, but contains more iron. It is quite plastic with water, calcines to a light buff color, and fuses before the blow-pipe into a grey slag.

ANALYSES OF CLAYS OF THE BLUFF AT HICKMAN, FULTON COUNTY.

Air Dried.	Beneath Gravel.		Decending Order Beneath No. 2136.				Above Low Water	
	¼ Mile North of Hickman.	Refractory Clay, Hickman.	Unrefractory Greyish Clay.	Refractory Clays.				Unrefractory Clays.
				Bluish Joint Clay.	Greenish Yellow Clay.	Greenish Joint Clay.	95 ft.	45 ft.
	No. 2137	No. 2136	No. 2139	No. 2140	No. 2138	No. 2141	No. 2135	No. 2134
Silica	71.340	83.380	71.080	74.100	83.500	77.960	76.860	64.800
Alumina	17.190	9.800	19.050	16.460	9.940	13.970	14.600	21.070
Iron peroxide...	2.770	2.120	2.810	2.700	2.500	2.390	3.020	5.270
Lime	1.612	0.963	0.627	0.358	0.358	0.134	0.425	1.400
Magnesia	0.209	0.187	0.403	0.185	0.173	0.163	0.308	0.050
Potash	0.925	0.617	0.578	0.559	0.539	0.797	0.736	0.646
Soda	0.232	0.118	0.225	0.135	0.109	0.124	0.257	0.202
Water, etc.....	5.722	2.815	5.227	5.501	2.881	4.462	3.794	6.562
Total	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000

Dr. Robert Peter said of these clays: "It is evident that the Tertiary bluffs, from which these clays were collected, offer some valuable materials to the industrial arts. Some of these are quite refractory in the fire, especially Nos. 2136, 2138, 2140 and 2141, and would, probably, make good fire bricks, etc.; others of them could be employed for terra cotta work and other forms of pottery, while some of these abundant deposits might, no doubt, be used with advantage, in mixture with the more calcareous soft material found in some of these beds, in the manufacture of hydraulic cement of the character of the celebrated Portland cement."

B. CLAYS OF THE COLUMBUS BLUFFS.—The bluffs that face the Mississippi river at Columbus, and at the "chalk banks" two miles below, rise more than one hundred feet above the town, the upper portion composed of thirty feet each of grey silt or loess and gravel. Beneath the gravel there is a bed of variegated colored plastic clay, fifteen feet in thickness. Beneath this there are about eighty-five feet of silicious clays, bluish when freshly exposed, but on drying become greyish and highly indurated. The bed incloses fragments of stems, bark and leaves, and belongs to the Lignitic division of the Tertiary formation. The bed in the Columbus bluff is not continuous, but has been cut away in that portion lying nearest the town, and its place filled with thin beds of clay and indurated sands of the Lagrange group. It also forms the bluff that rises immediately from the water's edge at the "chalk banks." The three analyses that are given below are of this bed, and Dr. Peter reports that they are all very infusible before the blow-pipe, and burn hard to a light cream color. Their refractory character in the fire makes them useful for fire-brick, though the high percentage of potash probably unfits them for use in glass works where an extreme heat is employed. Their fine silicious character might also make them useful as a scouring material.

These beds are exposed in the bluffs east of the town; the silicious clays in the deep ravine by the Clinton road, and the upper plastic clays in the face of the bluff, south of the railroad cut, and by the road leading down the edge of the bottom. At the "chalk banks," the silicious fire-clays have again been cut away on the north side, and in their place we find the interstratified beds of fine plastic clays and white sand.

The same is true of the bluffs north of the Columbus exposures, none of the silicious beds having been observed until a short distance beyond Laketon, after which they are seen as far as Wickliffe occasionally, and northward to Cane creek. Belonging, as they do, to the lower or lignitic Tertiary formation, we naturally find them, further east, associated with the belt of dark clays in McCracken and Graves counties. Analyses of specimens from several localities are given below:

No. 2715. *Fire-clay*, from the bluff above Columbus, Hickman county; taken sixty-five feet above low water. It is plastic, and owes this property to the state of very fine division of

the large quantity of silicious sand which it contains; its 10.260 per cent. of alumina being equivalent to only 25.920 per cent. of kaolin, the basis of true clay.

No. 2162. *Clay,* from the bluffs in the upper part of the town of Columbus, Hickman county. This is the same bed as the preceding; is of a light grey color, almost white, and quite sandy. It is plastic, burns hard, and of a light cream color.

No. 2161. *Clay, from the "chalk banks,"* two miles below Columbus, Hickman county. It burns hard, is refractory before the blow-pipe, only sintering a little.

ANALYSES OF WHITE AND SILICIOUS REFRACTORY CLAYS OF HICKMAN COUNTY.

Air Dried.	Bluffs North of Columbus.		Chalk Banks 2 miles South of Columbus.
	No. 2715	No. 2162	No. 2161
Silica	85.180	84.918	76.360
Alumina	10.260	10.560	14.951
Iron peroxide	1.120	1.102	2.109
Lime	Trace	0.572	0.325
Magnesia	0.064	0.108	0.173
Potash	0.954	0.651	1.171
Soda	0.146	Not Est.	0.125
Water, etc.	2.276	2.089	4.786
Total	100.000	100.000	100.000
Sand	.....	68.500	69.000

The clays from the bluffs north of Columbus are the most refractory, and, in composition, compare well with the German glass-pot clay—containing less iron and a little more potash. The alumina percentage is low, though perhaps sufficient. At any rate, the clays of both Columbus and the "chalk banks" are fully worth a trial at an intense heat.

C. White or Light Colored Plastic Clays.—These are found in greater or less beds in each of the counties, but be-

long especially to the formation known as the Lagrange group of the Teritary, and were deposited since the deposition of the black clays. They are usually white or light purple in color, highly plastic when dry, adhering strongly to the tongue, and when cut present a very smooth, unctious surface. The beds vary in thickness from a few inches to many feet. The chief localities of occurrence are as follows:

No. 2640. *White pipe clay, from Rufus Morris place,* three miles east of New Providence, Calloway county. [This place is on the New Providence and Cypress Creek Road and is at present date (1905) owned by Mr. Eli McClure.] It is overlaid by about ten feet of loam and gravel. The bed is made up of two inches of white sand, overlying another bed of about eighteen inches of white clay, which rests upon a thin layer of ferruginous sandstone. The latter separates it from the bed of black, pyritous clay, No. 2641, described elsewhere (in the "Jackson's Purchase Report"). The thickest part of the bed contains small pockets of a fine white sand, and occasional spots of ochreous clay. This clay, at the Rookwood Pottery, made a white biscuit when unglazed, but, on being glazed, became of a brownish-white color, unsuited to the finer classes of ware.

No. 2643. *White plastic clay, from Russell's pottery,* six miles northeast of Murray, Calloway county. [This place is on the Murray and Newberg Road. The clay is yet owned by Mr. W. K. Russell, who operates the pottery.] The section given is as follows: A surface covering of six feet of brown loam, four and a half feet of sandy clay, one foot of white clay, one and a half feet of black clay, and three feet of fine white clay, underlaid by brownish sandy clay and yellow micaceous sand. At the Rookwood Pottery this clay made a beautiful, light cream-colored ware. Dr. Langenbeck, at the time superintendent of the pottery, said of this clay: "With the addition of some flint, makes a very beautiful ivory-ware, almost exactly resembling that made by the celebrated firm of Copeland & Sons, in England, for table and toilet sets." It requires a high heat for burning, and would be improved by mixing with other clays.

[Clay from this deposit has recently (1905) been quite extensively shipped to clay-working industries in Covington and Newport. The section of the pit is materially the same as that

given above, except that in place of three feet of fine white clay near the bottom, it shows now of a thickness something like six feet.]

No. 2639. *White clay, from one mile east of Wyatt's schoolhouse,* in the northwest corner of Calloway county. [Two hundred and thirty-eight acres, including most of the exposures of this clay, is owned by Mr. John R. R. Lindrer, Cincinnati, Ohio. Thirty-eight acres of the territory, however, is owned by Mr. Ed P. Phillips, of Murray, Ky. The land is on the Mayfield and Murray Road, eight miles northwest of Murray.] This clay is very white, has a few ochreous spots, and is exposed at a number of points in the bank of a creek beneath a few feet of gravel and loam and in beds from three to ten feet thick, its true thickness being unknown. [Mr. Lindrer recently, in 1905, bored with a clay auger to a depth of twenty-five feet into this deposit without penetrating the entire thickness.] It outcrops also in the bluff at Backusburg. In places it has a bluish and in others a pinkish tint. The upper eighteen inches of the bed is usually of a mottled character, but altogether is highly plastic. Quantities of this clay have been shipped to the Evansville stoneware potteries, but the yellow ferruginous spots unfit it for such white ware. The Rookwood trials produced a brownish-white color when glazed.

[A. *B. Edwards' clay,* near the Mayfield and Murray Road, eight miles northwest of Murray, Calloway county. This clay is a continuation of the deposit noted one mile east of Wyatt's School-house, described under No. 2639 above. It is a white or light gray, plastic clay, covered by twelve feet of stratified Drift, or Lafayette Gravel, of the Quaternary, and the exposure shows a thickness of about five feet. The address of Mr. Edwards is R. F. D. No. 1, Kirksey, Ky.]

No. 2666. *Clay, from Howard's pottery, Bell City, Graves county.* [This clay is mined on property owned, near the pottery, by Mr. W. B. Howard. The pottery is at Rock (formerly known as Bell City), on the Mayfield and Paris Road, eighteen miles southeast of Mayfield.] The clay is of a light brownish-grey color with yellow ferruginous spots, and with some purplish, round and hollow concretions. It is infusible before the blow-pipe. The bed is from six to ten feet thick, and is used here in the manufacture of the ordinary brown jugs, jars, etc.

It burns at a moderate temperature, and, with a white slip-clay, would make cream-colored ware. [There are about eight feet of brown loam above the clay with a thin layer of gravel directly on the clay.]

No. 2663. *Stiff plastic clay, from Pittman's bank,* three miles west of Lynnville, Graves county. [This clay was owned and mined several years ago by Mr. J. W. Pittman, who operated a pottery near by. This property is on the Lynnville and Boydville Road, and is at present (1905) owned by Mr. Charles Snow.] The clay is very fine, of a brownish-gray color, and infusible before the blow-pipe. Its very stiff and intractable character compelled Mr. Pittman to mix with it a silty clay found in the hillsides near the pottery. The clay bed is very massive, its fresh, vertical surface showing very pretty lamination markings. The bed is exposed for ten or fifteen feet in thickness, is partly purplish in color, and holds some thin layers of fine sand. The tests at the Rookwood Pottery show a shrinkage of about ten per cent.; the unglazed biscuit is milky-white, but the glazing gives to it a brownish color.

No. 2141. *Clay from Wm. P. Arnett's land,* on Panther creek, six miles east of Mayfield, Graves county. [This property is still owned by Mrs. Wm. P. Arnett. It is on the Mayfield and Wadesboro Road.] The bed is exposed for about eight feet above the water, a bed of lignite appearing below the water at a point near by. The clay is bluish when wet, but grey when dry, and is quite sandy. It is quite plastic, and burns to a light salmon color, does not become very hard unless exposed to a very high temperature. It is refractory before the blow-pipe.

No. 2573. *Fire-clay, from the bank of the branch near the stave factory at Wickliffe, Ballard county.* [This is the clay of River Lot No. 6, owned now (1905) by a company composed of Chas. Wickliffe, J. W. Turk, A. Botkins and H. P. Garret, of Wickliffe.] This bed is exposed for a thickness of ten or twelve feet, and underlies a thin bed of lignite. It is again exposed in the bluffs between Wickliffe and Fort Jefferson. It is dark grey in color, highly silicious, with more than fifty-three per cent. of fine sand, and fuses with difficulty before the blow-pipe; it calcines white. The Rookwood Pottery tests show that it burns with moderate heat to a buff or light yellowish-brown color, and would make the Rockingham ware. [The

deposit is covered by from ten to twenty feet of Stratified Drift or Lafayette Gravel.]

No. 2568. *Refractory white clay, from one-half mile northwest of Blandville,* Ballard county. It is quite plastic, contains no appreciable coarse sand. It is infusible before the blow-pipe, and calcines white.

[This property is now (1905) owned by Mrs. Addie Marshall, of Blandville, Ky. The land is adjacent to Blandville on the north and the clay exposure is on Fulton Branch. The section here is as follows:

1. Loam ..... 10 ft.
2. Lafayette Gravel (Stratified Drift)..... 50 ft.
3. Stratum of limonite..... ¼ in.
4. Grey clay..... 15 ft.]

No. 2104. *Refractory clay, from near Moore's Mill,* one mile southwest of Blandville, Ballard county. It is exposed in the foot of the high bluffs that face the bottom lands of Mayfield creek.

[This property is near the Blandville and Bardwell Road and is owned by Mr. Henry Johnson (1905).]

At one point, a bed of lignite overlies the deposit. When freshly exposed it is bluish in color, but dries to a light grey color, nearly white, but with some yellow ochreous spots. It is quite plastic, calcines to a light salmon color, and is quite refractory before the blow-pipe. It contains nearly forty-eight per cent. of white sand, which was so fine that it was somewhat plastic when wet and adherent when dry. The shrinkage of this clay, as shown by tests at the Rookwood Pottery, is about fifteen per cent., and the ware made from it is colored dark buff or yellowish.

[*J. L. Turk Clay,* from Wickliffe and Blandville Road one mile west of Blandville, Ballard county. This clay is, in all probability, a continuation of the deposit described above. The exposure is at the foot of the bluffs of Stovall creek. The clay is very similar in appearance to the Henry Johnson clay except that it is possibly a little lighter in color when freshly exposed. The section of the exposure is as follows:

1. Gravel and sand (Lafayette)..... 18 ft.
2. White or greyish clay..... 4+ ft.]

No. 2571. *White Plastic Clay, from the banks of Cane creek, two miles north of Wickliffe, Ballard county.*

[Property owned by Mr. Philip Rollins at date of revision. Situated on Wickliffe and Cane Creek Road. A section of the present exposure shows fifteen feet of grey clay covered by five to ten feet of loess.]

This clay is silty in character, but quite plastic, as shown in the large percentage of alumina present. The bed has a thickness of several feet. It contains much fine white opaque sand; is infusible before the blow-pipe, and calcines white. It would make a good fire-brick, containing, as it does, comparatively little iron and potash in its composition.

[*I. C. R. R. Deposit*, one-quarter of a mile south of Wickliffe, Ballard county. Alongside the new railroad from Wickliffe to Mayfield there is an exposure of clay just out of Wickliffe, which shows the following section:

1. Loess	30 ft.
2. Gravel (Lafayette)	2 ft.
3. Sand and yellow clay	5 ft.
4. Grey clay	7 ft.
5. Lignite	2 ft.
6. Grey clay	8 ft.

This deposit is continuous with clay reported as No. 2573 on River Lot No. 6.]

[*River Lot No. 4*, in the northeast part of Wickliffe, Ballard county. Here there is a deposit of grey, plastic clay giving the following section:

1. Loam and Loess	10-30 ft.
2. Gravel (Lafayette)	3-10 ft.
3. Grey, plastic clay	20 ft.

This clay property is owned by a company composed of Dr. N. L. Rogers, Dr. J. C. Boone, Mr. Augustus Keppner and Mr. J. H. Tharp.]

[*The William Henderson Place*, one mile northeast of Wick-

liffe near the Wickliffe and Barlow Road. Here, there is a deposit of clay showing the following exposure:

1. Gravel (Lafayette)	3 ft.	(Hill, 30 ft.)
2. Ochreous clay	2 ft.	
3. Lignitic clay	10 in.	
4. Grey, plastic clay	7 ft.	

This exposure is at the base of a hill about thirty feet high and appears to be quite extensive horizontally as well as vertically. The deposit continues on to the property of Mr. B. F. Billington on the west.]

No. 2105. *Clay from the farm of T. D. Campbell,* near Laketon, Carlisle county.* [The property is owned at present (1905) by Messrs. C. Davis, T. J. Wilson and John Brashear. The deposit is covered by loam and gravel which varies at different points from five to thirty feet.]

The clay has a light purplish-grey color, with a few ochreous specks, and somewhat sandy. It is quite plastic, decrepitates strongly when exposed to heat, unless it is thoroughly dry. Calcines hard, and before the blow-pipe is quite refractory.

No. 4. *Clay from Mr. Samuel's farm,* four miles south of Blandville, Ballard county. [This farm is on the Bardwell and "Rose Cross-Roads" Road and is at present (1905) owned by Mr. W. Z. T. Smith. A section of the deposit follows:

1. Soil	1 ft.
2. Loam	2½-5 ft.
3. Gravel	2 ft.
4. Iron layer (limonite)	1 in.
5. Grey, plastic clay	4+ ft.]

This clay exhibits minute spangles of mica under the lens; heated before the blow-pipe, it becomes first dark colored, then burns white. [There is about one hundred and sixty acres of land underlaid by the deposit as shown by the outcrops.]

No. 2570. *Plastic Clay,* from George Ryan's place, on the north bluff of Little Mayfield Creek, four miles northeast of

*Was part of Ballard County when Dr. Loughridge's examinations were made.

Milburn, Carlisle county.* [This clay property is now (1905) owned by Mrs. E. J. Carrico. The exposure is along the Bardwell and Kirbytown Road.]

It is exposed in a number of places along the bluff with a thickness of four feet. It is very stiff, and contains some fine sand. It is infusible before the blow-pipe, and calcines to a light grey color.

[*Mrs. M. J. Reddick's Clay,* northeast part of Bardwell, Carlisle county. Here there is a yellowish-grey clay deposit at the base of the Stratified Drift or Lafayette Formation of the Quaternary, which shows the following exposure along the road leading out toward Blandville:

1. Soil and gravel	3 ft.
2. Iron layer (limonite)	¼ in.
3. Yellowish-grey clay	5+ ft.]

No. 2569. *Bluish Plastic Clay, from a ravine near the road, three miles east of Blandville, Ballard county.* [This is on the Blandville and Lovelaceville Road and the land is owned by Mr. C. Brown and Mrs. Ellen Linderman, on the north and south sides of the road respectively. The clay extends under land on both sides. The deposit is covered here by about seven feet of Brown Loam.]

On drying, it is of a light-grey color or buff; contains no coarse sand. Before the blow-pipe, it fuses with difficulty, and calcines to a light-grey color. It has an observed thickness of about three feet, and underlies a thin bed of red sand. [There is about one foot of gravel above this red sand and recent observations show the clay to be at least seven feet thick.]

[*Mrs. Walston's Clay.*—This deposit is in the southwest part of Bardwell, Carlisle county, and is owned by Mrs. E. (?) Walston. The property is along the Illinois Central Railroad and in a large gully to the west of the road one finds something like the following section:

1. Loam	20 ft.
2. Reddish and sandy clay	5 ft.
3. Drab, plastic clay	4-6 ft.]

*Was part of Ballard county when Dr. Loughridge's examinations were made.

[*The Wm. Reynolds Place.*—This is near the Columbus and Cairo Road, three miles north of Berkley, Carlisle county. Here there is a very pretty pink and yellowish clay at the base of the Lafayette Gravel showing the following section:

1. Loess	10 ft.
2. Pebbles and conglomerate iron	1 ft.
3. Pink and yellow clay	8 ft.

This exposure is along a branch or drain at the foot of high bluffs of Loess and may be traced around on the property of Mr. B. F. Gannaway on the south, and Mr. M. R. Holland on the east.]

No. 2759. *Micaceous Clay, from the place of F. N. Burradell,* five miles north of Benton, Marshall county.

[This property at date of revision is owned by Mr. Wm. W. Burradell, son of F. N. Burradell. It is located on the Briensburg and Gilbertsville Road one mile east of the State road from Benton to Paducah.]

The clay occurs in layers with white sand, and is interspersed with small pockets of the sand, but is otherwise quite plastic. It outcrops in several places, but its total thickness is not known. It is infusible before the blow-pipe and calcines hard. Washed in water, it left 70.33 per cent. of fine, whitish sand containing small mica scales. The Rookwood test gave a milky-white unglazed biscuit, which became a rather dark cream color on glazing. Its shrinkage is ten per cent.

[Recent investigations (1905) show this deposit to be covered by about four feet of soil and gravel and to be at least ten feet thick. The indications are that the deposit is very extensive, both horizontally and in thickness.]

No. 2763. *Micaceous Clay, from J. T. Pugh's place,* two miles east of Palma, Marshall county. [This property is at present date (1905) owned by Mr. L. Faust and is located near the Palma and Birmingham Road.]

When freshly exposed, it has a light, bluish cast, but becomes greyish on drying. It is plastic, and fuses with great difficulty before the blow-pipe. It holds small pockets of white sand, and has a thickness of several feet. The Rookwood test

produced a white unglazed biscuit, which, on glazing, became a dark cream color. Its shrinkage is about fifteen per cent.

[This clay is a continuation of the beds found on Mr. Wm. W. Burradell to the south. This deposit of grey or whitish plastic clay is everywhere overlain by the Lafayette Gravel and perhaps belongs to the Quaternary series, forming the lowest beds of that age.]

No. 2211. *Clay, from Mr. Munier's,* five miles south of Paducah, McCracken county. [Property now owned by Mr. Gus Munier. It is located on the Paducah and Mayfield Road.] The bed is massive and its thickness unknown. The clay is bluish when first exposed, but dries to a light grey color, nearly white, and mottled with a very light ochreous material. It is quite plastic; before the blow-pipe, it burnt hard, of a light gray color, nearly white, and finally fused with great difficulty. Tests made in the Rookwood Pottery gave a white unglazed biscuit, and showed a shrinkage of about 15 per cent. The clay is exposed on the side of a sloping hill, and has but comparatively little surface covering of earth.

[*On Mr. Richard Bell's place,* four miles south of Paducah, on the Mayfield road, McCracken county, there is a deposit similar to that at Mr. Munier's—doubtless a continuation of it. An analysis was made by Dr. A. M. Peter, Survey Chemist, of a sample taken by Mr. J. A. Bauer, proprietor of the Paducah Pottery. The sample may have been roughly washed. As received, the clay was nearly white, in small lumps which broke with an imperfectly conchoidal fracture. Following is the analysis:

No. 12972 of the Laboratory Book.

	Per cent.
Moisture	0.88
Ignition (combined water, etc.)	6.35
Silica	67.07
Alumina	20.72
Iron peroxide	0.99
Lime	0.25
Magnesia	0.09
Potash	1.59
Soda	0.17
Sulphuric anhydride	0.07
Titanic oxide	1.04
	99.22

Dr. Peter remarks on the very refractory silicious character of this clay, resembling in composition the German glass-pot clays of which analyses are given on page 343 of Volume A, Chemical Analyses, Kentucky Geological Survey, and, also, on a succeeding page of this report. The suggestion that the analysis was of clay which had, to some degree at least, been washed, occurs when comparison is made with the analysis of the Munier clay, No. 2211, hitherto described.]

[*The Victor Welch Clay.*—This deposit is on the Lone Oak and Mayfield Road, four miles southeast of Lone Oak and eight miles southwest of Paducah, in McCracken county. It is a light grey clay and has been used to some extent by Mr. J. A. Bauer in making stoneware at his pottery in Paducah. An analysis of a sample collected by Mr. Bauer, made by Dr. A. M. Peter, is given below. The sample analyzed consisted of a light grey or nearly white clay in small soft lumps, some of which showed occasional patches of brownish ochreous clay.

No. 12971 of Laboratory Book. Sample air-dried.

	Per cent.
Moisture	1.48
Ignition (combined water, etc.)	6.28
Silica	68.34
Alumina	18.82
Iron peroxide	1.64
Lime	0.35
Magnesia	0.36
Potash	1.40
Soda	0.22
Sulphuric anhydride	0.08
Titanic oxide	0.89
	99.86

Dr. Peter calls attention to the very refractory silicious character of the clay. Compare the analysis with those of German glass-pot clays given in this chapter.

The deposit continues southward from the Welch place on to lands of Mr. William Roof and Mr. William Grief. The thickness of the clay is not known; about four feet have been exposed. It is covered by four feet of gravel and seven feet of brown loam.]

Following are the analyses of the clays No. 2640, etc., noted in the preceding descriptions:

REFRACTORY WHITE OR LIGHT COLORED CLAYS.

	Calloway Co.			Graves Co.			Marshall Co.		McCr. Co.
AIR DRIED.	Morris' east of New Providence	Russells' six miles east of Murray.	Near Wyatts school house.	Howard's, Bell City.	Pittman's 3 miles west of Lyn'ville	Panther Creek east of Mayfield.	Burradell's 5 miles north of Benton.	Pugh's 2 miles east of Palma.	Munier's south of Paducah.
	No. 2640	No. 2643	No. 2639	No. 2666	No. 2663	No. 2141	No. 2759	No. 2763	No. 2211
Silica	61.680	57.840	46.020	56.980	62.680	75.550	84.580	62.920	64.480
Alumina	28.500	30.340	38.980	32.160	25.880	16.751	10.650	29.880	24.691
Iron peroxide	1.680	1.180	trace.	2.160	2.900	1.198	.330	trace.	1.869
Lime	.101	.011	.773	trace.	trace.	trace.	.137	trace.	.448
Magnesia	.136	.050	.136	.209	.319	.144	.101	.209	.137
Potash	1.158	.618	.309	.838	1.147	1.094	.954	1.564	1.457
Soda	.822	.518	.172	.111	.928	.216	.292	.172	.083
Water, etc.	5.923	9.442	13.610	7.542	6.146	5.047	2.956	5.255	6.835
Total	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000
Sand	.....	.....	.....	16.440	.....	63.000	70.330	.....	.....

REFRACTORY WHITE AND LIGHT COLORED CLAYS.

	BALLARD AND CARLISLE COUNTIES.							
AIR DRIED.	Wickliffe.	Blandville.	South-west of Blandville.	Cane Creek North of Wickliffe.	Campbell's near Laketon.	Four miles South of Blandville.	Four miles North-east of Milburn.	Three miles East of Blandville.
	No. 2573	No. 2568	No. 2104	No. 2571	No. 2105	No. 4	No. 2570	No. 2569
Silica	73.240	74.840	74.460	63.840	67.501	71.940	76.540	71.180
Alumina	15.760	16.580	18.070	26.040	23.051	20.700	14.820	20.800
Iron peroxide	1.920	1.400	1.633	0.740	2.109	Trace	0.960	1.780
Lime	0.325	0.269	0.314	Trace	0.257	0.370	Trace	Trace
Magnesia	0.519	0.209	0.245	0.137	0.065	0.350	0.331	0.101
Potash	1.467	1.293	0.940	0.714	0.412	0.630	0.926	0.247
Soda	0.147	0.283	0.021	0.207	0.020	.....	0.229	0.291
Water, etc.	6.622	5.126	4.317	8.322	6.585	6.200	6.194	5.601
Total	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000
Sand	53.490	.....	48.000	44.000	.....	.....	.....	.....

Of the above clays, that from near Wyatt's school-house, in the northwestern corner of Calloway county, is, by far, the richest in clay, and at the same time contains the least amount of alkalies and iron, and the highest percentage of lime. The bed itself, however, is more or less permeated with light streaks of yellow ochre, which would give to the whole more than a trace of iron. The next in purity, or in freedom from iron and the alkalies, is that from four miles south of Blandville, in Ballard county (No. 4), which contains but little more than half a per cent. of iron and alkalies. The two clays from Marshall county, and the specimen from Cane creek, immediatly north of Wickliffe, in Ballard county, come next, with their one and a half per cent., respectively, while in all other specimens the combined percentages of iron, potash and soda are above two per cent.

A few of the clays contain a very large amount of sand; but this would be separated from the finer material in the process of manufacture of any ware. The analyses are, therefore, calculated upon only the fine material.

[*J. R. Bowles' Clay,* near Lamont, McCracken county. A soft, white clay, having the appearance of kaolin. Thickness, 60 or more inches. Shows a face for about 100 yards horizontally. Analysis by Dr. A. M. Peter of air-dried sample:

	Per cent.
Moisture	1.19
Ignition (combined water and volatile matter)	5.38
Silica	72.56
Alumina	15.98
Ferric oxide	0.89
Lime	0.41
Magnesia	0.19
Potash	1.68
Soda	0.35
Titanic oxide	1.42
Sulphur trioxide	None
	100.05

Dr. Peter remarks: "A good, high silica clay, which should be quite refractory and ought to be valuable." This has been verified by a test made by Mr. John Geo. Bauer at the works of the Paducah Pottery Company. It burns nearly white. Mr.

Bauer, an expert potter, pronounces it a high-class ball clay.—C. J. N.]

D. BLACK AND BLUISH-BLACK CLAYS.—The clays of this division are confined to the Cretaceous and lower or Lignitic Tertiary belts that pass through Calloway, Marshall, McCracken, Carlisle and Ballard counties, and also to the Port Hudson division of the Quaternary, which occurs in the valley and bottom land of the three bordering rivers. The dark color is chiefly due to the decayed vegetable matter, which burns out with sufficient heat. The dark color is also intensified by moisture, becoming a lighter black on drying.

The clays of the Cretaceous and Tertiary divisions are very refractory, and would possibly make good fire-brick; but those of the Port Hudson contain so large an amount of iron and potash that they fuse with readiness before the blow-pipe.

No. 2641. *Black Plastic Clay, from Rufus Morris' place,* three miles east of New Providence, Calloway county."

[Property is on New Providence and Cypress Creek Road and owned at present by Mr. Eli McClure.] It underlies the white plastic clay No. 2640, and its thickness is unknown. On drying, it becomes a light slate color. It contains, in places, much iron pyrites in small rounded grains. It is imperfectly laminated, fine-grained, and its powder is quite soft.

No. 2642. *Stiff Dark Joint Clay,* or so-called "soapstone," from the bluffs of East Fork of Clark's River, at the Paris Bridge, south of Murray, Calloway county. It is the characteristic clay of the eastern outcrop of the lignitic Tertiary, reaching from the Tennessee State line northward to Paducah, and thence westward to Caledonia, on the Ohio River. Its thickness is, at some points, as much as ninety feet. It is more or less ochreous in character, its fractures or joints being usually permeated with yellow ochre. It is highly indurated and somewhat micaceous. Tests made at the Rookwood Pottery indicate that it can not be used for glazed ware because of the shivering of the glaze. It might be successfully used in the manufacture of water-jars, which require no glazing. The unglazed biscuit is pink in color. Mixed with an equal weight of the white plastic clay from Russell's pottery, east of Murray, it receives a good glaze, and makes a light chocolate-colored ware, dotted with black specks from the mica particles. [This

clay is exposed at many places over the territory around Murray, and all wells of any considerable depth penetrate and find their water supply in this dark joint-clay of the Lignitic Tertiary Age. Property showing the exposure at Paris Bridge is owned by the N., C. & St. L. Railroad, but it is found at various points along this branch of Clark's River.]

No. 2644. *Dark clay, from the place of J. H. Mahan,* six miles east of Murray, Calloway county. [This property is located near the Murray and Newberg Road and is owned by Messrs. John Jones and Henry Willoughby.] The clay is black when freshly exposed, but on drying becomes a purplish-slate color, and contains fine white sand and minute specks of mica. Its depth is not known, but must be several feet. It is here exposed in the side of a long sloping hill, and there are but a few feet of overlying material. The Rookwood tests produced a yellowish-white ware, a little darker than that from Russell's pottery, which is so highly admired.

Dr. Langenbeck, who superintended the tests, expressed the opinion that, mixed with a little flint, it would not require high heat, and would make very pretty cream-colored ware. The dark color of these clays seems to be due to the vegetable matter, which burns out, leaving a greyish mass. The alkali percentages are about what are found in the other clays, while that of the iron in the specimen from the Paris Bridge, near Murray, is very large, showing itself as a yellow ochre in the cracks and seams in the clay. The amount of lime is very small. [This clay is evidently at the top of the Lagrange-Tertiary and at the base of two to ten feet of Brown Loam and Lafayette Gravel.]

[*James Dulaney Place.*—This land is located near the Mayfield and Murray Road, eight miles northwest of Murray, Calloway county. The farm joins that of A. B. Edwards on the north. Along a branch near Mr. Edwards' home, there is an exposure of dark-grey, very pyritous clay. Iron pyrites occurs in the clay in two forms; it is disseminated in small grains through the clay and also in the form of round and oblong concretions. The deposit is covered by six inches of soil and five feet of gravel, as shown by the following section:

1. Soil and grass roots	6 in.
2. Gravel (Lafayette)	5 ft.
3. Dark, pyritous clay	2 ft.+

The upper two feet of the deposit (No. 3 of the section) are exposed for several hundred yards along the branch. The exposure is in timbered lands and a luxuriant plant growth is found above the bed.]

Following are analyses of the refractory black clays, No. 2641, etc., noted in the preceding descriptions:

REFRACTORY BLACK CLAYS.

AIR DRIED.	CALLOWAY COUNTY.		
	McClure's east of New Providence	At Paris Bridge, Murray	Jones & Willoughby north-east of Murray
	Black Plastic Clay	Stiff Joint Clay	Bluish Clay
	No. 2641	No. 2642	No. 2644
Silica	56.680	66.380	54.140
Alumina	29.700	16.480	32.140
Iron peroxide	1.480	3.500	1.040
Lime	Trace	0.213	0.011
Magnesia	0.281	0.497	0.032
Potash	1.004	0.928	0.965
Soda	0.274	0.228	0.468
Water, expelled at 380° F.	10.581	11.774	11.204
Total	100.000	100.000	100.000
Sand	.....	39.780	39.000

Comparison with German Clays.

A number of our Kentucky clays compare favorably in their analytical results with the German glass-pot clays, which are so celebrated for their great refractory character. As will be seen in the table given below, the percentages of iron and potash, the injurious ingredients, are comparatively little above those of the German clays, and in several instances one or the other is much less; while in the Calloway county clay, No. 2639, there is only a trace of iron, a small amount of potash, and very large percentages of silica and alumina, making this a far purer clay than the German; in fact almost a kaolinite or hydrous silicate of alumina, a mineral with the composition of silica 46.3, alumina 39.8, and water 13.9 per cent.

There is but little doubt that these clays can take the place

of the German clays in those establishments where they would be required to withstand the most intense heat. They are at least worth the trial. Transportation facilities alone are in favor of the German clays, which are brought over as ballast in vessels, and, therefore, at a very low cost to those who use them.

The German fire-clays are supposed to be the most refractory clays known, and are imported for the construction of crucibles to withstand a very high heat, but particularly for our glass manufacturers, who seem to agree that no other known clay will so completely withstand the great heat of their furnaces, and the fluxing influence of the melted glass, as this. It is consequently almost universally used as the material for the construction of the glass-pots or large crucibles in which the glass is made and melted. On a visit to the International Centennial Exhibition at Philadelphia, the attention of Dr. Peter, the Chemist of this Survey,* was attracted to an exhibit of this clay, made by J. Goebel & Co., importers of German clay and manufacturers of crucibles, etc., Maiden Lane, New York. It showed the clay in its natural and prepared conditions, and accompanying the specimens was a report of the chemical analysis of the material, said to have been made in Germany, a copy of which is given below. Dr. Peter also secured a sample from what appeared to be a washed and prepared specimen on exhibition, which had been moulded into a cubical block, and which he has analyzed.

Another specimen was obtained at the co-operative window-glass works, at the foot of Coal Hill, opposite Pittsburg, from a barrel of the material which was said to be in the condition in which it was imported from Germany. Its analysis was also made by Dr. Peter, and is given below.

H. German Clay, obtained at the Centennial Exposition. It is of a light grey color; adheres strongly to the tongue, and exhibits a large irregularly conchoidal fracture. Before the blow-pipe, it fused only on the extremity of the small pointed fragment into a white slag.

I. German Glass-pot Clay, obtained at the co-operative window-glass works in Pittsburg. This had not been re-worked or

* Reference is to Dr. Robert Peter, deceased, father of Dr. A. M. Peter, present Chemist to the Survey.

washed. It resembles the preceding, but is a little more friable and slightly lighter colored. Its powder, however, is somewhat darker than the powder of that. Before the blow-pipe, it acted like the preceding.

J. Copy of the analysis of this clay made in Germany, as exhibited by J. Goebel & Co.

No. 2639. Refractory Clay, from one mile east of Wyatt's school-house, in the northwestern part of Calloway county, Ky.

No. 2162. Refractory Clay, from the bluffs at Columbus, Hickman county.

No. 2571. Refractory Clay, from Cane creek, two miles north of Wickliffe, Ballard county.

No. 4. Refractory Clay, from four miles south of Blandville, Ballard county.

No. 2643. Refractory Clay, from Russell's pottery, six miles east of Murray, Calloway county. The clay is pre-eminent for the beautiful cream-colored ware made from it at the Rookwood Pottery, Cincinnati, O.

The above Kentucky clays have been described on a previous page, and their analyses given.

COMPARATIVE ANALYSES OF GERMAN GLASS-POT CLAY AND KENTUCKY CLAYS.

Dried at 212 Degrees Fahrenheit.	German Clays.			Kentucky Clays.				
				Calloway Co.	Hickman Co.	Ballard County.		Calloway Co.
	H	I	J	No. 2639	No. 2162	No. 2571	No. 4	No. 2643
Silica and sand.	70.860	73.660	70.600	46.020	84.918	63.840	71.940	57.840
Alumina	20.900	19.460	23.600	38.980	10.560	26.040	20.700	30.340
Iron peroxide...	1.560	1.560	.....	Trace	1.102	0.740	Trace	1.180
Iron sulphide...	.....	.....	1.100	.....	.....	.....	.....	.....
Lime	0.347	0.168	0.360	0.773	0.572	Trace	0.370	0.011
Magnesia	0.220	0.209	0.450	0.136	0.108	0.137	0.350	0.050
Potash	0.578	0.520	Notest.	0.309	0.651	0.714	0.630	0.618
Soda	0.112	0.046	Notest.	0.172	Notest.	0.207	.....	0.519
Water, expelled at red heat...	6.800	6.200	*3.890	13.610	2.089	8.322	6.200	9.442
Total	101.377	101.823	100.000	100.000	100.000	100.000	100.000	100.000
Sand	4.000	3.500	.....	.....	.....	44.000	.....	.....

* Organic matter and loss.

UNREFRACTORY CLAYS.

Clays of this class, which yield more or less readily to the heat of the blow-pipe, and fuse into slag, are found in a number of the counties, but seem to be chiefly confined to those lying on the eastern side of the Purchase region, viz.: McCracken, Graves, Marshall and Calloway; all of those examined on the west being entirely or nearly infusible. They vary in color from nearly white to dark black, some of them highly gypseous, and two others having a sprinkling of specks of the mineral vivianite, a phosphate of iron.

Geologically they are older than the Quaternary, and, as the class of infusible clays just described, are covered by the gravel, sand and brown loam of that period. They embrace some of the white varieties belonging to the intermediate period between the Tertiary and the Quaternary, and the black clays of the next higher or Port Hudson group. As will be seen from the analyses given below, they differ from the refractory class in having a larger proportion of potash and iron, which imparts to them their fusible character.

The following are some of the localities examined, and the composition of the clay from each is given below:

No. 2777. *Stiff Clay, from a deep ravine on the place of W. J. Jones,* four miles south of Paducah, McCracken county.

[This property is yet owned by Mr. Jones, but the mineral right is at present held by Dr. R. R. Winston, of Paducah, Ky. It is located on the Paducah and Mayfield Road.]

The bed has an exposure of several feet, the central six inches of which is very brittle, with some yellow ochre. It is overlaid by fifteen or twenty feet of gravel and loam. When freshly exposed it has a bluish color, which changes on drying to a greyish tint. It fuses with difficulty before the blow-pipe, and calcines white. The Rookwood tests produced a buff-colored unglazed biscuit, and showed a shrinkage of about fifteen per cent.

No. 2779. *Gypseous Clay, from W. J. Hough's,* four miles southwest of Paducah, McCracken county. [This property is now owned by Mr. G. R. Noble. It is on the Paducah and Blandville Road.]

This clay has an exposure of about five feet, and contains small pockets of fine needle crystals of gypsum; it is in places somewhat sandy with ochreous spots. It is exposed in the bank of a branch, and has but a few feet of surface covering of gravel and loam. It calcines white, and fuses slightly before the blow-pipe. The Rookwood Pottery test shows a shrinkage of about twelve and a half per cent., the glazed biscuit having a dark cream or light buff color.

[A report made for Mr. Noble, in 1903, by Lucius P. Brown & Co., Nashville, on a sample of clay which is understood to have come from this deposit, is as follows: "This clay is of the type known among potters as 'ball clay,' and is used in the composition of various white glazed products, for the purpose of imparting plasticity to the otherwise non-plastic ingredients. It is of excellent plasticity, without being sticky. The burned sample was obtained in a regular pottery fire of more than the usual degree of heat (pyrometric cone 10), the common fire being usually cones 7 and 8. The behavior of the clay in this heat was good; it attained vitreousness without blistering. Its shrinkage was moderate, straight and without cracks. Its color that of average English ball clay. The specks show its impurities, which are not over the average amount. To prove its value as a bond for fire-bricks, etc., it was necessary to make a fusion test in the Deville furnace. This test showed that the clay fuses at cone 27 and its quality, therefore, is that of a second-class fire-clay, good for a plastic bond clay.—C. J. N."]

No. 2778. *Purplish Plastic Clay, from north bluff of Mayfield Creek, three miles east of Lovelaceville, McCracken county.* The exposure is about three feet thick, and variegated in color from white to purple and yellowish. It is sandy in places, and fuses to a grey color before the blow-pipe. [The north bluffs of Mayfield creek are high and precipitous, and at their base there is a frequent exposure of a whitish and purplish clay. This is but one of many places at which it may be found along the creek.]

No. 2664. *Stiff Plastic Clay, from the railroad cut immediately south of Guill Hill* and three miles south of Wingo, Graves county. [The property is owned by Mrs. (Della ?) Copelin

and the clay is now (in 1905) mined and used by the Water Valley Pottery Company, Water Valley, Graves county, Ky.]

This clay has a bluish cast when fresh in the bed, but dries to a whiter color. It is fused with great difficulty before the blow-pipe. A section of the exposure shows surface loam five feet, gravel one to three feet, thin and uneven purplish clay a few inches, indurated red sand in thin laminae, somewhat clayey, three feet, and the bed of the above plastic clay, three feet of which is exposed at the foot of the bank. The tests made at the Rookwood Pottery produced a brownish biscuit even when unglazed, whose shrinkage was, however, only seven and one-half per cent.

[The mine or pit had fallen in when visited in 1905, so that a new section could not be accurately gotten, but it does not differ materially from the foregoing, although the old section was not made at the place of the open mine or pit.]

[*The Clay Switch Mine.*—This clay mine is on a short switch to the Illinois Central Railroad, four miles south of Mayfield, Graves county. General shipping and filling of special orders is the object of the mining, which is done by The Kentucky Construction and Improvement Company, of which Mr. Morris B. Cooley, of Pryors, Ky., is secretary and general manager. The sales agent for the company is Mr. C. N. Forster, No. 112 Washington street, East Liverpool, Ohio.

The mining is done by tunneling the upper five layers of the deposit. They pinch and swell from two to four feet, and are practically the same clay except for the slight difference in shrinkage. Mr. Cooley gave assurance that the entire deposit was extremely thick and that it had been penetrated, as a test, to a depth of one hundred feet. The clay averages a light grey color, but some is stained very dark by vegetable matter which burns out. The deposit is at the top of the Lagrange-Tertiary and, at the mouth of the main tunnel, is overlaid by from four to six feet of Lafayette Gravel.

This clay is often shipped to considerable distances, as Newport, Cincinnati and East Liverpool. The company, so far, is unable to keep pace with the demand and many orders are necessarily cancelled.]

No. 2665. *Plastic Clay, from the hillside immediately north of Boaz Station, Graves county.* [This clay is owned and mined by Mr. J. A. Bauer, of the Paducah Pottery, Paducah, Ky. There is a mixture of soil and sand above the deposit about ten feet thick. It has been mined just north and about one-quarter of a mile south of Boaz on the Illinois Central Railroad.]

The bed is composed of three feet of a creamy-white clay, underlaid by two feet of a stiff purple clay, both containing impressions of fossil leaves; a sand underlies the bed. But little trouble is experienced in getting out their clay for shipment or local use, as the surface covering is but a few feet thick until the bluffs are reached some distance eastward.

The white clay, tested at the Rookwood pottery, burned at a low temperature and made a biscuit rather too dark for cream-colored ware, though, when unglazed, it is milky white.

[An analysis of a sample of clay collected from this locality by Mr. Bauer was made by Dr. A. M. Peter. The sample, which consisted of a soft, nearly white clay, in small lumps, showing occasional iron stains, was labeled, "From Boaz, Ky., 14 miles from Paducah and ¾ mile from station known as Anderson farm." The analysis is given below, together with that made of sample collected by Dr. Loughridge, No. 2665, for comparison:

	No. 12973. Anderson Farm. Collected by J. A. Bauer.	No. 2665. Hill N. of Boaz. Col. by R. H. L.
Moisture	0.45	.....
Ignition (combined water, etc.)	4.66	5.82
Silica	74.95	61.92
Alumina	15.28	30.06
Iron peroxide	0.83	0.30
Lime	0.15	Trace
Magnesia	0.14	0.06
Potash	1.45	1.60
Soda	0.24	0.24
Sulphuric anhydride	0.07	Not Est.
Titanic oxide	1.34	Not Est.
Totals	99.56	100.00

It will be noticed that No. 12973 indicates a very refractory clay, carrying considerably more silica than No. 2665, and only about half as much alumina. The Rookwood test of No. 2665 placed that sample in the comparatively unrefractory class. It may be that the two samples did not come from the same bed, or that they were not collected under the same conditions; otherwise the analyses would indicate considerable variation in the composition of the clay within a short distance.]

No. 2760. *Plastic Clay, from H. S. Gray's place,* in the bed of a branch immediately south of Scale, Marshall county.

[This property, at date of revision, is owned by Mr. L. Lofton. The deposit is covered by about fifeen feet of loam and gravel of the Quaternary; about eight feet is the thickness of the clay exposed.]

The clay is bluish when freshly exposed, but dries to a greyish-white and contains some spots of yellow ochre, with some fine sand in thin laminae. It fused before the blow-pipe. The Rookwood test gave a buff-colored glazed biscuit.

No. 2762. *Dark Clay, with small specks of deep blue vivianite from the Tennessee River Landing at Highland, Marshall county.* [The property is now owned by Mr. S. A. Whale.] On drying, this clay becomes a light greyish-brown color. The particles of vivianite are frequently white on being freshly exposed, but turn blue on drying. The bank of the river here is made up of a surface deposit of seven feet of micaceous loam, fifteen feet of interlaminated light-bluish clay and yellow sand, ten feet of blue micaceous clay in layers of one and two feet thickness, with some yellow sand and ferruginous concretions. The lower clay bed contains the vivianite. The large amount of iron and potash in this clay causes it to fuse before the blow-pipe. On burning, it makes a dark red biscuit, and mixed with fine sand would make nice pressed brick and terra-cotta.

No. 2781. *Blue Micaceous Clay,* with small particles of vivianite, from a deep ravine, opening into the Ohio, in the west edge of Paducah, McCracken county. This clay, like that of Highland, just described, is interlaminated with a yellow sand, and overlaid by eight or ten feet of loam. Before the blow-pipe it fuses to a grey mass.

No. 2780. *Micaceous Clay, from Mr. Armstrong's place,* one-half mile east of Borings Ford, on Clark's river, or seven miles southeast of Paducah, McCracken county.

[This farm, under which the clay is found, has been divided. At present (1905), the central portion is owned by Mr. John Sheehan; the northern portion is owned by Mr. Rudolph Strite, and the southern portion by Mr. Stephen Ward.]

The clay is very sandy and micaceous, bluish when wet, but dries to a dark grey color. The thickness is unknown. [Penetrated to a depth of twenty feet in Mr. Sheehan's well.—J. H. G.] The upper six inches has a yellow color, the whole overlaid by but a few feet of gravel and loam. Before the blow-pipe it fuses to a grey color. At the Rookwood Pottery the ochre gave to the biscuit a handsome deep brick-red color. The shrinkage was about twelve per cent.

Following are analyses of the clays described:

ANALYSES OF UNREFRACTORY CLAYS.

AIR DRIED.	LIGHT COLORED CLAY.							BLUISH OR DARK CLAY.	
	McCracken County.			Graves County.		Marshall County.		McCracken County.	
	Jones', Three miles South of Paducah.	G. R. Noble's, Four miles S. W. of Paducah.	Mitchell's, 3 miles East of Lovelaceville.	Guill Hill South of Wingo.	Boaz.	L. Lofton near Scale.	Highland Landing on Tenn. River.	Paducah.	S. E. of Paducah (formerly Armstrong's.)
	No. 2777	No. 2779	No. 2778	No. 2664	No. 2665	No. 2760	No. 2762	No. 2781	No. 2780
Silica	59.500	67.580	66.320	75.120	61.920	52.580	60.980	73.192	69.220
Alumina	24.960	20.040	22 930	15.960	30.060	31.070	18.480	16.540	17.540
Iron Peroxide	.720	.540	1.190	1.420	.300	1.510	7.500	1.840	1.440
Lime	.325	[a] 1.743	.437	Trace	Trace	.137	.780	.369	.437
Magnesia	.396	.158	.209	.317	.064	.245	1.128	.461	.858
Potash	1.934	1.340	1.107	1.351	1.602	1.775	2.664	1.969	2.452
Soda	.286	.075	.470	[a] .245	.239	.318	.627	.541	.472
Water, etc.	11.879	8.524	7.337	5.587	5.815	12.365	7.841	5.088	7.581
Total	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000
Sand	.....	.....	.....	.....	.....	.....	.....	56.60	50.580

[a] Mostly gypsum.

In all of the above analyses the percentages of potash are very high, that of the vivianite clays of Highland Landing and Paducah being exceptionally so. The soda percentages of the last two are also very high, the combined alkali percentage of the Highland clay being thus raised to over three and three-tenths. The clay containing the next highest alkali percentage is that of the Armstrong place, east of Paducah, which, though extremely sandy in character, has nearly three per cent. of potash and soda. In general, all of these unrefractory clays contain a larger amount of alkali than do those of the refractory class, while in the iron percentages the differences are not so great. In the latter the Highland beds again stand out prominently with their seven and a half percentage.

Ochreous Clays.

At a number of points in the Purchase counties there are beds of clay so highly colored with yellow ochre as to make them useful as coloring pigments, and they have been used for this purpose to some extent locally. On burning they become oxidized into a bright red color. They would also make the beautifully red pressed brick so much in demand for house fronts.

In addition to these, there are certain bluish clays which, on burning, make a very pretty red brick. One of these beds outcrops in the banks of the Tennessee river at Highland Landing, Marshall county. Its analysis and description are given on a previous page. An analysis has been made of but one specimen, and that from near Wickliffe, Ballard county.

In Ballard county there are three prominent localities of occurrence, near Wickliffe and Laketon, respectively. At the former place the clay is exposed in a deep ravine that cuts into the hill north of the town, on the Harkless place. The bed is apparently several feet in thickness, beneath fifty feet or more of loam and gravel. It is rather difficult of access. The clay is a bright yellow, quite free from sand, and has been used in Wickliffe as a paint for wagons. It fuses before the blow-pipe into a black slag. Tested at the Rookwood Pottery, it made a bright red biscuit, which, on glazing, became black. Its shrinkage is about seventeen per cent. Its analysis is given below.

No. 2572. "*Yellow Ochre, from the Harkless place,* immediately north of Wickliffe, Ballard county. On calcining, it becomes a handsome Venetian red color, and fuses before the blow-pipe into a blackish mass. [Found also on John Rothrock's place. Thickness, six feet.]

COMPOSITION OF THE OCHREOUS CLAYS OF BALLARD COUNTY.

Silica	44.840
Alumina	22.831
Iron peroxide	20.350
Lime	0.101
Magnesia	0.138
Water, etc.	11.740
Total	100.000

Another exposure of this bed is seen in the deep ravine that cuts northward into the hills from Fort Jefferson, south of Wickliffe. Near Laketon, in this county, there are two exposures, one on the land of Mr. Hogancamp, two miles north of Laketon, and which also occurs at the foot of a deep ravine, opening westward into the Mississippi bottom, and with a thickness of two feet or more. It has a bright yellow color and is quite free from sand. On Sandy creek, two miles south of Laketon, the ochre is again exposed in a bed several feet in thickness (said to be ten), near the residence of Mr. T. J. Wilson, and extending down the creek some distance toward the Mississippi bottom, near which it is found embedded in rounded and large lumps in the heavy beds of white sands. It is somewhat interlaminated with whitish clay and is quite plastic. It contains about twenty-six and a half per cent. of a fine white sand, composed of rounded grains of transparent quartz; there is present also a little mica in very fine particles. The ochre may be easily separated from the sand by washing and allowing the latter to settle while the ochre remains suspended and is poured off with the water. The clay calcines to a bright red color, and fuses before the blow-pipe to a black slag.

In McCracken county there is a bed of ochre about six inches thick, comprising the upper portion of the clay bed on the "Armstrong" place*, one-half mile east of the Boring Ford on Clark's

*Now owned by Messrs. Sheehan, Strite and Ward. See note under No. 2780, preceding.

river, or seven miles from Paducah. It is somewhat sandy in character, but burns to a dark red brick, and with a shrinkage of about fifteen per cent. It contains much sand, but this can be separated from the ochre by washing.

At Wadesboro, in Calloway county, another, but thin, bed of yellow ochre occurs in the gully immediately east of the store-houses that line the street. The clay is jointed in structure, and forms the upper surface of the black joint-clay, or so-called soapstone, that is characteristic of this eastern lignitic belt. It has a bright yellow color, its iron being derived, doubtless, from the superincumbent ferruginous gravel and sand; the bed is from six to ten inches thick. The clay calcines to a handsome red color, and before the blow-pipe fuses to a black color. Its shrinkage on burning is about fifteen per cent.

[*The Richard Bell Place.*—This property is on the Paducah and Mayfield Road, four miles south of Paducah, McCracken county. Here there is an area of more than fifty acres underlaid by an ochreous, plastic clay from six to twelve feet thick. There is a grayish, plastic clay at the bottom, of which an analysis—samples taken by Mr. Bauer—has been given. The ochreous deposit is covered by about nine feet of gravel, cemented at the bottom more or less with iron oxide. This clay is being mined by Mr. Bell and shipped for paint purposes to George A. Methan Co., St. Louis, Mo. It appears to be an excellent clay.]

Sands.

Deep beds of sand, varying from pure white to red and yellow, occur in several of the geological formations represented in the Purchase counties. These formations are the Cretaceous, the Lagrange division of the Tertiary, and the stratified drift of the Quaternary. The massive quartzite rocks that outcrop at certain points south and southwest of Paducah, and in east Calloway county, would, if crushed, make a very clear and pellucid sand, suitable for glass manufacture. The grains are sharp, and quite free from iron stains.

The sand-beds of the Cretaceous, occuring east of Murray, in Calloway county, and near Benton, in Marshall county, are very deep, and highly charged with fine particles of mica, which

give to it a sparkling appearance. The grains are sharp and the sand can be used as a coarse polishing material.

In Calloway county the beds are well exposed as the cross roads northeast of New Concord and southward in the hills facing the valley of Beechy creek. The sands are variegated in color, but mostly white, and are slightly calcareous. The analyses by Dr. Peter given below show them to be quite free from impurities.

The sand-bed occurring on the north side of Clark's river, and two miles from Benton, Marshall county, is well known as the "Sand Hill." It underlies a black clay and is stratified, its layers having a southeasterly dip. The upper part of the bed has a yellowish color from the iron, in solution, brought by percolation from the overlying beds, but, in the main, is white and micaeous, and holds thin layers of a plastic clay. Its exposure is from six to ten feet, being hidden below by the debris from the bluff above. A few concretionary forms of sand, cemented with iron, occur occasionally in the sand. The analysis of this sand is also given below.

No. 2636. *Fine Micaceous Sand,* slightly calcareous; Cretaceous formation. Taken from a heavy bed, two miles northeast of New Concord, Calloway county.

No. 2637. *Sand,* apparently similar to the preceding, but slightly colored light-brownish with iron oxide. Taken from the same locality as the above.

No. 2758. *White Sand,* Cretaceous formation, taken from the Sand Hill on the north side of Clark's river, two miles north of Benton, Marshall county. A fint hyaline quartz sand, with a yellowish tint. Contains small mica specks.

ANALYSES OF SANDS.

	Calloway County.		Marsh'll County.
	Near New Concord.		Near Benton.
	No. 2636.	No. 2637.	No. 2768.
Organic and volatile matters	1.815	0.690	0.395
Alumina, iron oxide, etc.	0.605	0.505	0.323
Lime carbonate	0.090	0.095	Trace
Magnesia	0.232	Trace	0.017
Phosphoric acid	0.044	Trace	0.093
Potash	Not Est.	0.289	0.189
Water expelled at 380° F.	.....	.....	0.054
Sand and insoluble silicates	97.395	98.145	98.989
Totals	100.181	99.724	100.057
Hygroscopic moisture	0.075	0.025	0.050
Potash in the insoluble residue	0.074	Not Est.	0.001

The Tertiary sands, belonging to the Lagrange group of the interstratified sands and pipe clays, are usually quite white, and, in large part, of the clear hyaline variety. The beds between the clay strata vary in thickness, and could, with some difficulty, be kept free from clay admixtures. The beds are most largely exposed at points along the bluff facing the Mississippi river bottom, from the mouth of Mayfield creek southward to Columbus. A prominent exposure is at the water tank one mile south of Laketon, the bed here rising about fifty feet above the railroad track. The sand is, however, intermixed with two per cent. or more of fine clayey particles, which injure it for the manufacture of fine glassware. The grains are rounded and largely of hyaline quartz, mixed with some very fine sand.

In the bluffs north of the town of Columbus, there is a very thick bed of fine white sand, colored, in part, from iron percolations from the gravel above, and composed of over ninety-nine per cent. of pure hyaline quartz grains.

All of the above Cretaceous and Tertiary sands would be

useful in the manufacture of any but the finer kinds of glass ware, in mixing with the stiff plastic clays for the manufacture of pottery, etc., and in mixing with mortar and cement.

The sand of the stratified drift is very generally colored yellow and red from iron oxide, which injures it for any but ordinary uses. The beds are found interstratified with the gravel, and also alone in the southwestern part of the Purchase counties.

Polishing Powder.

There are several localities within the Purchase region in which occur beds of a fine silicious earth, or sharp, silty sand, which could be utilized as a polishing powder for silver or other metals. The most prominent of these places is at Pryorsburg, Graves county. The beds are here exposed in a bluff a short distance east of town, on the east of the first branch. There are two grades of the powder in this bluff, one made up of extremely fine and sharp grains, one thousandth of an inch in diameter, whose grittiness between the fingers is just perceptible, while the other grade is a little coarser, the diameter of the grains being about twice as large as the former. A little clay accompanies the powder. The thickness of the entire bed is unknown, as there is a large amount of debris at the foot of the bluff.

The bluff shows about fifteen feet of loam and gravel, and ten feet of purplish plastic clays, above these beds of fine sand, which are exposed ten or fifteen feet thick, and slope to the northeast. The beds are much indurated, but the powder readily yields to attrition. Put up in packages it should find a ready sale as a polishing powder.

Another bed of fine silty or arenaceous clay, also suitable as a polishing material, occurs in the railroad cut three miles north of Boaz Station, Graves county. It is very similar to the beds of decomposed Subcarboniferous chert of the eastern part of Marshall and Calloway counties, a few pieces of the rounded chert being embedded in it. It is light brownish-grey in color, indurated, or of the hardness of chalk, and contains about two and a half per cent. of very fine white sand. From the analysis which is given below, it will be seen that it contains a very large

amount of potash, as indeed do most of the clays of the region. It is refractory before the blow-pipe, and fuses with great difficulty. Many of the clays of the Purchase counties are more or less arenaceous, and might serve the purpose of a polishing or finishing material.

The beds of decomposed chert of the Subcarboniferous belt, along the west side of the Tennessee river, are made up of a white, non-plastic, silicious earth, indurated, but friable and easily crumbling, and which is infusible before the blow-pipe.

In Marshall county this earth is exposed in the bed of the branch on the place of Mrs. Lou Stone, four miles west of Birmingham, and at several points nearer town fragments of undecomposed and angular chert are enclosed in the beds.

In Calloway county the white earth is more prominently and extensively developed in the hills bordering Blood river on the east, in the neighborhood of Brandon's Mill. The beds are here exposed for ten or more feet in thickness above the bottom of the ravines or branches, and are made up of alternating layers of chert and silicious earth. The same beds are also found eastward in the hills facing the Tennessee river, in the region of Buffalo Landing.

All of these silicious earths are very similar in their composition, being chiefly silica, with some alumina and potash, as will be seen from the analyses given below.

No. 2662. *Arenaceous Clay,* from the railroad cut three miles north of Boaz, Graves county.

No. 2764. *Silicious Earth*, or decomposed white chert, from Mrs. Lou Stone's place, four miles west of Birmingham, Marshall county.

No. 2638. *Silicious Earth,* from Brandon's Mill, on Blood river, Calloway county.

No. 2761. *Ash-colored Earth*, from a cistern on the old Winters place, eight miles southeast of Olive post-office, Marshall county.

COMPOSITION OF SILICIOUS EARTHS.

	Graves County.	Marshall County.	Calloway County.	Marsh'll County.
	3 miles North of Boaz.	4 miles West Birmingham.	Brandon's Mill.	Winter's Place.
	No. 2662.	No. 2764.	No. 2638.	No. 2761.
Silica	76.780	93.700	87.300	91.580
Alumina	14.740	3.580	10.480	5.980
Iron peroxide	1.640	.....	Trace	0.220
Lime	Trace	Trace	0.045	0.045
Magnesia	0.389	0.127	0.281	0.055
Potash	1.440	0.618	0.888	0.094
Soda	0.117	0.117	0.209	0.032
Water	4.894	1.858	0.797	1.994
Total	100.000	100.000	100.000	100.000
Sand	2.400	.....	.....	.....

The earths from Marshall and Calloway counties, being very fine and highly silicious, with very little of such fluxing materials as iron-oxide, lime, soda and magnesia (though the potash percentage is high), could be well used to mix with plastic clays to reduce their shrinkage, and also as scouring and polishing bricks. They might also be used in glass making.

INDUSTRIES FOUNDED ON THE PURCHASE CLAYS.

[There are in various parts of the region a number of potteries engaged in the manufacture of ordinary brown jugs, jars, crocks, flower pots, etc. These potteries are generally crude and worked at a very small expense. They are distributed, at the date of revision, as follows: The most important pottery of the Purchase, considering the extent of the factory and the modern methods of manufacture, is the Paducah Pottery, operated by Mr. J. A. Bauer, at the corner of Seventh and Trimble streets, Paducah, McCracken county. Mr. Bauer manufactures various kinds, sizes and shapes of Bristol glaze stoneware and flower pots, together with growlers, mugs, cuspidors, filters, measures, coolers, jars, nappies, bail-handle jugs, druggists' jugs, flue thimbles, churns, crocks and vases. The clays from which these articles are manufactured are gotten from various points. A considerable quantity is obtained from Mr. Bauer's mines at Boaz, in Graves county, on the Illinois Central Railroad.

[At Pottertown, six miles east of Murray, on the Murray and Newburg Road, Calloway county, there is a pottery operated by Mr. W. K. Russell. Here are manufactured hand-made jars, jugs, crocks, flower pots, churns, etc., from a clay elsewhere described as the Russell clay which is mined near the pottery.

[Another pottery is located at Bell City, or "Rock," eighteen miles southeast of Mayfield, on the Mayfield and Paris Road, Graves county. This pottery, until a short time ago, was operated by Mr. W. B. Howard and son. The work has recently been discontinued on account of Mr. Howard's ill health. The clay used was a grey, plastic clay mined on property owned by Mr. Howard adjacent to the pottery. This clay described later as the Howard clay was manufactured into hand-made jugs, jars, crocks, etc.

[A pottery operated by the Water-Valley Pottery Co., with Mr. O. O. Lassiter as manager, is located at Water Valley, on the Illinois Central Railroad, in the southern part of Graves county. The clay which they manufacture into ordinary articles of pottery such as have been named above, is obtained from the farm of Mrs. Della (?) Copelin, four and a half miles north of Water Valley, near the I. C. Railroad.

[The Mayfield Pottery has not been in operation for two or three years, but will likely be continued soon. It was last operated by Messrs. Morris Cooley and Robert A. Hale. The clay used was obtained from Clay Switch, near Pryors, in Graves county, now mined by the Kentucky Construction and Improvement Company.

[There is a pottery at Columbus, Hickman county, now managed and owned by Messrs. Lewis Schenk and William Rocker. They manufacture churns, jars, milk-pans, cuspidors, flower pots, etc. The clay is obtained principally from what is known as "Chalk Banks," two miles south of Columbus, on the Mississippi River banks, elsewhere described.

[Another pottery, known as the Wickliffe Pottery, is located at Wickliffe, the county seat of Ballard county. This pottery is owned and operated by Mr. Augustus Keppner. Mr. Keppner manufactures ornamental flower pots, jugs, jars, crocks, etc., from clay mined on Keppner's Acre and River Lot No. 4, described elsewhere in this report.

[The old pottery, three miles south of Lynnville, on Lynnville and Boydville Road, has been discontinued for several years. It was owned and managed by Mr. J. W. Pitman. The clay used was mined near by, from land now owned by Mr. Charles Snow, and yet known as "the Old Pitman Bank."

[There are a number of brick plants over the Jackson Purchase engaged in the manufacture of pressed brick, as follows: Hill & Karnes, Katterjohn's Sons, and Chamberlain & Murray are the three brick plants of Paducah, McCracken county. The clay used at these plants is a stiff bluish or dark clay belonging to Dr. Loughridge's Port Hudson division of the Quaternary. Each plant has a capacity of about 25,000 per day. Hill & Karnes use the C. & A. Potts brick machines. Katterjohn's Sons and Chamberlain & Murray use the Jonathan Craiger and Arnold Craiger machines, respectively. The Arnold Craiger is the new name for the old Jonathan Craiger machine.

[At Mayfield, there are two brick plants—McDonald Bros. and Mayfield Brick Company. The McDonald Bros. use the Wallace machine of the Wallace Manufacturing Co., Frankfort, Ind., and work the upper three feet of the Brown Loam of Quaternary Age, which covers the greater part of the Jackson

Purchase. Capacity, 20,000 per day. The Mayfield Brick Company uses the Berg Dry Press Machine put out by the Anderson Machine Works, of Anderson, Ind. Capacity, 20,000. The clay used for the manufacture of their brick is mined on property owned by the company, two miles east of Mayfield. They make a beautiful white brick, decked with dark specks.

[At Murray, the county seat of Calloway county, there is a brick plant, not in operation at present, but owned by Mr. A. J. Slaughter.

[At Hazel, in the southern part of Calloway county, there is a plant operated by the Hazel Brick and Tile Co. Their machinery is obtained from the American Clay Machine Co., Ohio. The company is composed of Messrs. S. S. and L. A. Callicott. They use the Brown Loam of Quaternary age mixed with grey clay from Purrier, Tenn., just across the Kentucky-Tennessee line.

[The Bardwell Brick and Tile Plant is located just south of Bardwell, Carlisle county, and is operated by J. E. Mantel, W. L. Mosby and Dr. W. L. Elliston. The company has so far manufactured no tile at all, but have made a considerable quantity of brick. The machine used is "the Little Wonder," put out by the Wallace Mfg. Co., Frankfort, Ind. Capacity, 20,000. The clay used is the upper three feet of soil and Brown Loam.

[G. H. Bransford & Son own and operate a brick plant at Fulton, Fulton county. They use a Henry Martin Machine, of Lancaster, Pa. Capacity, 20,000. The clay used is the upper ten feet of Brown Loam.

[These are the principal brick plants of the Purchase, but it is not to be understood that they are all the brick plants. The revision work being done in a hasty manner, it is probable that some of the smaller plants of the district have been overlooked, and apologies are hereby made for the necessarily hasty and scouting nature of the work.]

CHAPTER IV.

Clays in Crittenden and Livingston Counties.

BY F. JULIUS FOHS.

PROFESSOR C. J. NORWOOD,
Director, Kentucky Geological Survey.

SIR: In answer to your request, I herewith submit data relative to clays, the descriptions of which, in the main, will be incorporated in my Livingston report and the remainder, for the most part, in the general report of this mineral district. The descriptions include: Notes on the clays of the Lafayette formation; on laterites or residual clays; on dike clays; on the fire-clay or fire-sand of the Stevens Tunnels, and of the Angling Property, with a note on the comparative value of this product and Dinas brick; and descriptions of miscellaneous clay and shale occurrences, including some of value for paints and fertilizers.

Very respectfully,
F. JULIUS FOHS,
Assistant Geologist.

Marion, Ky.,
September 26, 1905.

LATERITES OR RESIDUAL CLAYS.

The term laterite or residual clay is here used for that type of superficial deposit resulting from rock decay *in situ*, regardless of the kind of sedimentary rock from which it is derived. Such a deposit covers the rocks of the various geological formations for a thickness varying from nothing to twelve feet or more, though usually six to eight feet thick. It generally consists of two layers more or less distinct. The upper layer shows such little difference in the several formations, it may be residual of, that in the majority of cases they can not be told apart. The

lower layer is usually intermediary in character between the upper layer and the character of the formation it results from. In general, it may be said that the two layers are more distinct where resulting from limestone, and much less so from a sandstone formation. The upper layer bears some resemblance to the loess of the Columbia formation, such as is found in the Mississippi Valley, and may be said to differ from it principally in the loess being more calcareous, of lighter, usually of even texture, and containing calcareous concretions or "loess kindchen," as well as land snails, etc. Stony particles are also less frequent in the loess than in laterite. The latter often contains segregations of white silt one to two inches wide. The erosion forms of laterite are usually quite rugged and ridgy in appearance, along gullies and cuts, and nowhere shows straight walls such as are often found in the loess. Specimens of laterite were collected from the several formations, and will be described below, in more detail from each of them.

The Birdsville laterites, upper layer, are used for the manufacture of brick by two concerns at Marion, while that from the St. Louis has been used for like purpose near Irma, in Crittenden county, about fourteen miles northwest of Marion. The lower red layer of the St. Louis and Princeton limestones, would also make excellent brick. The general distribution of the clays of both layers make quite a large amount of the material available for brick manufacture. The bricks produced are generally of good quality. The Princeton (Ste. Genevieve) laterites on further decomposition produce the best soils.

Birdsville Laterites.—A light brown sandy clay, that is porous and contains decaying roots. It is quite plastic and cakes in large lumps, which are quite coherent when dry. Contains few or no sandstone fragments. Found above Birdsville sandstone on the Golconda Road, two and three-quarters miles from Lola, in Livingston county. Another specimen collected about a mile to the north, on the Carrsville Road, does not differ from it. These were samples of the upper layer, the lower not being exposed.

On Wring Bluff, near the old Wring house, about twelve feet lower than the top of the bluff, and at a height of about 36 feet above Claylick creek, specimens were collected of sandstone well up in the Birdsville. The lower layer is more minutely

porous than that first described, but of the same sandy character and plastic. It is also not as evenly colored, a little more white and reddish brown alternating in different parts. The upper layer is darker in color than the lower, a thing rather unusual, being a little darker in color even than that below described from the upper layer from near Paradise Church. It is more coarsely sandy than the upper layer, and contains a few rootlets.

Another typical instance may be mentioned. This is notable in the road cut, about one and three-quarters miles from Marion, on the Salem Road, on Foster Hill. Here the upper layer contains small sandstone particles and is of light brown, while the lower layer only differs from it in being of a brick red color. The latter rests on Birdsville sandstone shales. This deposit is not so far advanced in the processes of decay as those described above.

Princeton (Ste. Genevieve) Laterites.—Specimens collected from above the calcareous sandstone or Rosiclare member of this formation, on the Marion-Salem Road, near R. A. LaRue's house. The upper layer laterite is more porous and lighter colored than any of those previously described. Its color is gray-white with a little brown. It is plastic and slightly gritty. That from the lower layer is red, sandy and somewhat plastic, showing evidence of being a decomposition product of the calcareous sandstone.

Specimens collected from the road in front of Mr. Robinson's, near Lola, are probably from above the Fredonia member. The lower layer is a deep red clay, sandy to a small extent, residual of limestone and chert. Does not effervesce in acid. Small particles of chert through the clay, with a less number of larger fragments. This chert is compact and but slightly porous. The upper layer is darker in color, containing more red than the Golconda Road laterite, and contains a little white coloring admixed. Slacks in water, is porous and somewhat plastic. It is quite finely sandy and shows a slight tendency at lamination.

Another specimen from above the Fredonia member was collected near Mr. Tolly's house, on the Lola-Carrsville Road. It is from the lower layer, and is a plastic red clay with some yellow and black stains. Contains disseminated fragments of a compact chert.

St. Louis Laterites.—Specimens were collected from above the cherts and iron ore of the St. Louis formation, about a half mile southeast of Paradise Church, in Livingston county. The upper layer is very similar to the Golconda Road product, except that it is a slight shade redder and not as porous or coherent. The lower layer is a deep red clay, slightiy sandy. It is quite plastic and contains chert fragments.

In the cross-cut at the 45-foot level of the Mann No. 4 shaft, a red clay residual from the limestone is secured. It is somewhat laminated, sandy and plastic, and contains slightly more sandy yellow streaks, making it not as dark as the one previously described.

On the Sheridan-Tolu Road, near John Perry's house, a specimen was collected from the upper layer above St. Louis chert. For the most part it contains more red in color than the Golconda Road laterite. Is exceedingly porous. Shows a slight tendency toward lamination. Contains no rock fragments. Seams, on the other hand, have whiter clay containing decomposing rock fragments.

Clays of the Lafayette Formation.

The Fire-clays.—Within a radius of three miles of Smithland and on the south side of the Cumberland river, there occur a number of exposures of a hard silicious fire-clay, very similar to the under-clays of the Carboniferous coals, except that it is permeated by casts of decayed rootlets. This clay lies unconformably on rocks of the Mississippian series, notably on those of the St. Louis and Birdsville formations. It is capped by a highly ferruginous sandstone or chert conglomerate, and sometimes by both. The clay, together with the rocks that cap it, belong to the Lafayette formation of late Neocene age. Besides being used as a fire-clay, it is also thought to be of value for cement.

The deposit most extensively exploited occurs two and six-tenths miles from Smithland on the Haddock's Ferry Road. It was operated by A. M. Hewlett from 1899 to 1902. It is now owned by the Western Clay & Mining Co., who succeeded Mr. Hewlett. No work is being done at present. Entries, which were driven on either side of the road, were caved at the time

of the writer's visit. Mr. Charles Bush, the superintendent, informs the writer that on one side of the road the entry had been driven back 600 feet, and worked for a length of about 500 feet; on the other it was driven back 175 feet and was 100 feet in length. They were operated by the room and pillar system. About 8,000 tons were shipped. Where outcropping in the road, it is covered by thin, irregular layers (in one place two feet thick) of ferruginous sandstone containing rounded chert pebbles, which gave the surface of the rock a nodular or humped appearance. Loose Lafayette pebbles and brown loam, doubtfully the equivalent of the Columbia formation, cover this to the top of the hill. The clay varies from four and a half to six and a half feet in thickness. It rests unconformably upon the St. Louis formation, upon horizontal beds of jointed cherts. Horses of these, sometimes five feet thick, are said to occur in the clay. It is a bluish white silicious clay, porous and quite hard and flinty in character. It has root markings and hollow root casts through it, somewhat iron stained. Becomes plastic to a small extent after being ground. As a fire-clay it is said to produce fire-bricks of excellent quality, and was used by the Western Tube Co., of Kewanee, Ill., to whom it was shipped for their furnaces. No analyses of the clay are available.

Two other notable outcrops of this clay occur, and these are on the Paducah Road. The first is about one and three-fifths miles from Smithland, on the brow of the hill after passing the well bored for oil. The clay here rests unconformably upon a thin bed of greenish shales of Birdsville age, which in turn lies upon a heavy bed of limestone of the same formation. The clay is about five and a half feet thick. A thin, broken layer of ferruginous sandstone is superimposed upon it, and above this are Lafayette pebbles. The clay is little different from that previously described, but the root markings and iron stains are less notable.

The second outcrop is about one hundred and twenty yards from the above, at a higher altitude, and laying most probably upon Birdsville sandstone. The clay is about six feet thick and about the same in character as the above. It does not soften or slack, even on remaining in water for several hours. About a barge load has been shipped from the road outcrop by its owner, Mr. F. B. Moody. Similar deposits are said to outcrop

on either side of the by-road leading from the Paducah Road to Echo Valley Spring. Another outcrop was said to occur a little farther up the Paducah Road, but was covered by debris at the time of the writer's visit.

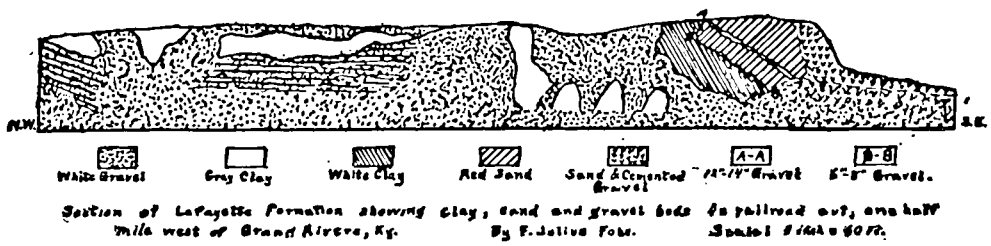
It seems probable that this bed of clay will prove fairly continuous under the area in this section covered by the ferruginous sandstone and Lafayette pebbles, and that quite an industry might be built up by its development.

Still another outcrop of clay was noted in the Lafayette formation, capping the Birdsville limestones of Cemetery Ridge, where crossed by the Smithland-Grand Rivers Road. This clay differs somewhat from those previously described, not being as hard, being more highly silicious, and containing some iron oxides. It shows partial stratification. Section of the upper part of the hill, including this clay and resting on limestone, is as follows:

1. Brown loam.....7 to 11 ft.
2. Reddish clay..... 5½ ft.
3. White clay..... 5½ ft.
4. Covered ..... 5½ ft.

Clays in the Gravels.—Irregular masses of clay of grey and white color occur in the gravels of the Lafayette formation as exposed along the railroad opposite the Grand Rivers Furnaces, one-half mile west of Grand Rivers, in Livingston county, and in the gravel pits, one and a half mile west of the same place.

A section is shown herewith showing the distribution of clays in this formation. This section shows the most typical portion of the outcrop of the clays and gravels exposed to north of railroad opposite the Grand Rivers Furnaces. It is in the main self-explanatory. There is a thin covering of soil up to six inches thick.



Section of Lafayette Formation showing clay, sand and gravel beds in railroad cut, one half mile west of Grand Rivers, Ky. By F. Julius Fohs.

The white clay shown in outcrop was only one exposed. It was from ten to twelve feet thick, dipping about thirty-five degrees southeast, and the lower portion covered with gravels. The clay is very plastic, generally white, with very slight yellow stains, and at outcrop contains occasional rootlets. It is not gritty, slacks readily and leaves a small amount of fine silt on being slacked in water.

The gray clay is a little darker in color and more porous at the outcrop, otherwise but little different in character from the white. As will be noted from the section, it occurs in very irregular masses. Another lower partially-developed layer of this clay is to be seen just northwest of the section herewith given.

Clays of Gravel Pits.—Clay gray to white, and practically same in character as that just described above. The clay here also lays in all possible positions, though sometimes, as shown in the New Pit, as a seam two to three feet thick dipping at an angle of 60 degrees and again in almost horizontal seams.

Dike Clays.—The basic igneous intrusive, filling the dikes in Crittenden county, weathers readily to a golden colored clay. The clays from the several dikes are so similar that a general description will suffice. In color, they vary from a bright golden yellow with occasional streaks of red, where from near the surface, to a green, containing few or no red streaks, in depth, becoming harder and more solid, as well as darker in color as the state of the fresh peridotite is approached. The clay consists principally of golden-yellow mica, altered phlogopite. The clay is somewhat plastic, very slightly gritty; does not effervesce in strong acid. As the dikes are often four to twelve feet wide and are weathered sometimes to a depth of forty feet, and as there are seven or eight of the dikes, some of which are known to be three to four miles in length, and probably extending much further, besides which sheets and sills occur, quite an amount of this clay would be available, could some use be found for it. Tests made so far by private parties to ascertain a use for it have not been satisfactory. Both a chemical analysis and physical tests would be of value.

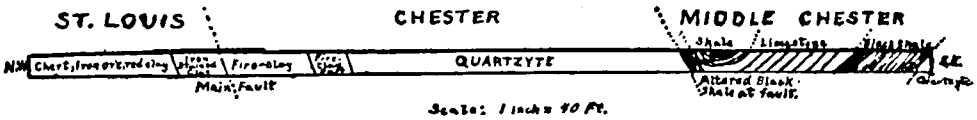
Deposits on Fault Lines.

Stevens' Fireclay Tunnels.—Operated by the Western Clay and Mining Company, of Kewanee, Ill., of which Mr. A. M. Hewlett is president.

They are located about twelve miles from the Illinois Central Railroad at Marion, being on Loudy Hall creek, on the line between Crittenden and Livingston counties, about two miles a little south of east of Salem. They may be reached by the Salem-Dycusburg Road, taking the first left-hand road on reaching the Cox Spring branch.

They are situated on one of the principal fault stress lines of the Western Kentucky Mining District. Fire-clay, or fire-sand (the product being very high in silica and low in alumina), occurs along the fault plane. The walls of the main fault are St. Louis limestone and cherts on the northwest and probably Lower Chester quartzite on the southeast, with a probable minimum displacement of three hundred and fifty to four hundred feet. The fault bears N. 32 degrees E. This seems to be broken by a cross-fault bearing N. 7 degrees W., indicated by a swag in the hill and displacing the portion of the main fault that is west of it, to the north about one hundred feet. The fault after displacement shows no material change in character of filling.

The main tunnel is reached by two short cross-cuts into the hill, Entries Nos. 1 and 2. The tunnel is over three hundred feet long and twenty to thirty-five feet in width, according to the width of the fire-clay or fire-sand. It is thirty to forty feet in height, the product being taken out up to grass roots, so that the tunnel has now caved.



Vertical Cross-Section of Stevens Tunnels from No. 1 Entry. By F. Julius Fohs.

The No. 1 Entry was continued across the tunnel and into the county rock to the southeast, making a total distance of two hundred and sixty-five feet passed through by it. A vertical section of it is presented herewith, which is, in the main, self-

explanatory. At one hundred and ninety feet out, or one hundred and twenty-nine feet from the main fault, a secondary fault occurs, between the Lower Chester quartzite on the northwest and Middle Chester shales, limestone and quartzite on the southeast. At this fault occurs a plastic black clay about three feet thick, noted on the vertical section as an altered black shale, which it is taken to be.

The third entry is made into the hill two hundred and twenty-seven feet southwest of No. 1 Entry. It is carried southeast about seventy-five feet, where a shaft has been sunk in it, and continues a short distance southeast from it. It is also extended to the southwest from the shaft and then to the northwest, finally intersecting the St. Louis Limestone wall. Between its mouth and the shaft, brecciated St. Louis cherts, cemented with limonite and hematite, occurs in part through red clay. Nearer the shaft there is chert through a highly silicious gray clay. Passing southeast from the shaft, quartzite is encountered with some fire-clay or fire-sand through it. Passing southwest from the shaft, for twenty feet or more, a pinkish-brown lustrous sand, consisting in the main of very small, elongated quartz crystals, so small as to be barely visible to the naked eye, increasing in size to some at least one-sixteenth inch in diameter. It contains also small particles of quartzite. After this, gray and white plastic clays, kaolinic in character, occur in segregations. Further along, a finely divided pink clayey sand occurs, very similar to the pinkish-brown lustrous sand above described, but containing, besides the tiny longitudinal quartz crystals, small particles of a non-gritty yellow clay, and some of it contains large leached angular quartzite fragments stained pink by the anhydrous iron sesquioxide. After this, cherts, with more or less red clay, and finally the limestone is encountered.

The shaft is ninety-five feet deep. According to Mr. C. H. Stevens, who had charge of sinking it, the shaft was sunk through quartzite boulders for the first twenty feet, then chert and limonite through red clay was passed through for the next twenty feet, when they seemed to dip out of the shaft to the southeast. More clay was mixed through below this till within ten or twelve feet of the bottom a black clay was reached, containing finely disseminated pyrite or marcasite.

At the fifty-foot level two cross-cuts were made. The north-

west one was seventy-five feet long and brecciated cherts with limonite and hematite cement through red clay and some gray clay was secured. Cross-cut to southeast, eighteen feet about same, except that possibly some quartzite was secured, but this not certain, as the product may be highly silicified chert.

At the eighty-foot level another cross-cut was carried out about one hundred and eighty-seven feet. A descriptive section of the several bands passed through in it is presentod below. This section is on same side of cross fault as the section above given. Section beginning in shaft and continuing southeast to end of cross-cut is as follows:

1. In shaft, black clay with pyrite or marcasite through it, about six feet.

2. In cross-cut, chert breccia with iron cement, partially massive and partially boulders through sand, about twenty-two feet. At fifteen feet from shaft there is a fresh-water spring.

3. Chert boulders through fire-clay or sand rather dark in color, seventeen feet.

4. Some hematite boulders noted. Here sets in a three-foot band of black clay with disseminated pyrite or marcasite.

5. Masses of black clay similar to above through white clay, and some brown clay with occasional quartzite boulders, together with a few cherts, thirty-three feet.

6. Black clay similar to No. 4. Four to five feet thick and dipping southeast.

7. A brownish-yellow very plastic non-gritty clay for nineteen feet; its northwest contact with No. 6 probably marks line of main fault, as no cherts are found beyond contact to southeast.

8. Grey-white silicious clay, with a considerable amount of Lower Chester quartzite fragments and boulders, for fifty-two feet.

9. Black shales dipping highly to southeast, containing plant impressions, with some quartzite intercallated. The contact between these and No. 8 marks plane of secondary fault between Lower Chester quartzite and Middle Chester shales, limestone and quartzite.

They had gone but seven feet into these shales at the time of my visit, but according to Mr. Charles Bush, who had charge of the work, they continued across them for eight feet further,

making fifteen feet in all, after which they also cut through the following:

10. Coarse-grained blue-gray limestone, eight feet.

11. Black shales, seven feet.

12. White, highly silicified quartzite to end of cross-cut, seven feet.

The products shipped were the highly silicious fire-clay from the main tunnel and the black plastic clay secured in the cross-cut beyond the main tunnel, as above described; of this latter only one or two carloads were shipped.

The main mass of fire-clay or fire-sand is composed of finely-divided particles, having fragments of quartzite and chert through it. While these fragments show angularity as regards shape, they are often irregular, presenting a hackly appearance along the edges. The quartzite fragments show tiny cavities where leaching has occurred, lined with a thin layer of white clay, much whiter than the quartzite, and in some instances residual particles in the center. Some fragments show a more advanced stage of decomposition and leaching than others, and the breaking into each other of these small cavities accounts for the irregularity of the quartzite fragments along their edges. There are also small segregations of iron through the product from the size of a pin head and others over one-half inch across. The chert fragments also show evidence of having undergone silicification, and are usually smaller in size than the quartzite fragments. They show very little leaching, having minute cavities, capable of being seen only under a magnifier. The chert fragments are whiter and less translucent than the quartzite.

An analysis which I have seen of an average sample of the fire-clay or fire-sand shipped showed a little less than 94 per cent. of silica, a little less than 3 per cent. alumina, .50 per cent. iron oxides, and the remainder calcium and magnesium carbonates, soda and moisture. It is probable that part of the silica is colloidal, thus accounting for its having a greater plasticity than it would otherwise have with the same chemical composition.

It is probable that both mechanical and chemical means entered into its genesis. The faulting produced a highly brecciated mass of sandstone on the southeast of the main fault and brecciated limtstone and chert on the northwest. Probably heated

solutions, as suggested by Dr. H. F. Bain, have metamorphosed the sandstone by the addition of silica, changing it to quartzite, and also silicifying the cherts of the limestone. Later, a set of probably descending solutions passing along the fault plane have dissolved out the limestone, leaving red clay, limonite, hematite, cherts in part disintegrating into a highly silicious clay as residuals. The same solutions acting on the quartzite formed first tiny cavities in it, and continuing finally disintegrated it to its present condition. Later, other solutions have segregated small masses of more plastic kaolinic clays. The fact that part of the cementing silica was probably colloidal would account also in part for the ready disintegration of the quartzite. Tiny cavities showing leaching of quartzite are very common throughout the district, where the quartzite occurs along the faults. Summing up, the fire-clay or fire-sand is primarily derived from the quartzite, and in a lesser degree from the cherts.

The tunnels were started September 27, 1902, but no shipments were made till April, 1903. They were started with the intention of securing an ore body along the fault, when the fire-clay or fire-sand was found instead.

Shipments as secured from the Illinois Central Railroad and submitted in a report on the statistics of production of the district for incorporation in the report of the State Inspector of Mines for 1903-1904, were as follows: Shipments for 1903, five months, 8,696,793 pounds; shipments for 1904, three months, 3,260,000 pounds; a total of 5,978 short tons.

The product is used by the Kewanee Tube Company, Kewanee, Ill., for lining their furnaces, for which purpose it was considered very efficient.

A number of deposits somewhat similar to that of the Stevens fire-clay or fire-sand are noted below. All the occurrences mentioned have St. Louis limestones and cherts on one side of the fault and Chester quartzites on the other. In a number of instances, a small amount of similar products are found.

J. Anderson Jones Property.—Within one and a half miles of Sheridan, Crittenden county. Investigated by the Marion Zinc Company. The deposit was of considerable width, but showed too large a per cent. of ferric oxide to be of value.

John Eberle Property.—Two miles southeast of Salem, Livingston county. Shaft sunk about ninety feet. The product contains more chert than that at Stevens'. The size of the body is not known.

The Corn Mines.—Nine miles northwest of Marion, Crittenden county, at Pleasant Grove Church. A kaolinic clay, very white and pure, similar to the segregations at Stevens' Tunnels is secured, occurring between quartzite masses and between fluorspar fragments to one side of the quartzite. It is not found in commercial quantity.

The Angling Property.—This land is situated seven and a half miles from Smithland, to the north of the Tiline Road, in Livingston county. Here a shaft thirty feet deep has been sunk by Mr. W. A. Dooms, of Tiline. On the southeast side of the shaft a somewhat broken, irregular quartzite wall is secured, while on the northwest is found a calcite-seamed limestone. Some cherts and quartz geodes were found on the dump, making it probable that the limestone belongs to the St. Louis formation, although the geology here appears to be exceedingly complex. The main mass of clay, which constitutes the filling between the walls, contains chert, quartz and quartzite fragments, and it is consequently quite silicious. It is slightly plastic, and some parts show slight ferric oxide stains, while others are heavily stained. This fire-clay or fire-sand, on the whole, is quite similar to the Stevens' Tunnels product. The extent of this deposit has not been determined. A thin band of a much more plastic clay occurs immediately against the limestone wall. It is a light greenish yellow, somewhat speckled with brown iron stains; is not gritty, but unctuous.

It is of interest to note that the analyses of fire-clay or fire-sand, such as is secured at the Stevens' Tunnels, Angling, Jones, etc., show a close analogy to the composition of Dinas brick. Analyses of the Stevens clay, as previously noted, showed a little less than 94 per cent. silica, a little less than 3 per cent. alumina, 0.50 per cent. iron oxide, and the remainder calcium and magnesium carbonates, soda and moisture. The Dinas brick con-

sists of about 95 per cent. silica, 2 to 3 per cent. alumina and iron oxides, and 1 to 2 per cent. lime.*

The advantages of Dinas brick over firebrick have recently been pointed out, in an abstract of a paper of F. Leisse on the subject (in Engineering and Mining Journal, LXXX., No. 3, 120), and may be summed up as follows:

Firebrick, in the construction of certain kinds of furnace, especially retort furnaces (in which tight walls are requisite), is weak in its high coefficient of contraction when exposed to high temperatures, the shrinkage being 5 to 7 per cent. at 1,300 degrees C. This and the tendency to soften when heated quickly lead to deformation of retorts.

On the other hand, Dinas brick withstands a higher temperature than firebrick, and increases slightly in volume, the linear expansion in good samples being 0.9 to 3.4 per cent. at 1,700 degrees C. Furnaces built of Dinas brick are found to bear fluctuations of temperature very well, and, as the walls can be built thinner than when firebrick are used, the larger combustion chambers thus possible facilitate the utilization of heat, pyrometric tests showing a superiority of 70 degrees C. Though more porous than firebrick, it is less corroded by flying ash and chemical agents, and there is no cracking of the pillars as with firebrick, the heat being more uniformly distributed through the mass. Its conductivity is 20 per cent. higher than the best firebrick, the quality being apparently due rather to the relative percentage of silica and alumina than to structure.

These facts should be good cause for larger exploitation of the fire-clay or fire-sand secured along faults in this section.

*"Dinas bricks" are of English manufacture and are also known as "English quartz bricks," or as "stone bricks." As in the case of the "silica bricks" of France and Germany, they are especially designed to retain form and size under intense heat, and are much used in the construction of copper furnaces at Swansea. They are made of quartz sand or of crushed quartz rock, with small percentages of alumina and lime, the lime being the binding material. The average composition of Dinas brick is as follows:

	Per cent.
Silica	95.93
Iron oxide	0.48
Alumina	1.20
Lime	2.15
Magnesia	0.24
Manganese oxide	Trace
	100.000

It will be seen that the Stevens' Tunnels material compares well with the Dinas analysis.—C. J. N.

Descriptions of Miscellaneous Clay and Shale Occurrences.*

David Adams Shale.—Exposed in a gully on the east of road, about a mile and a half from Smithland, on the Dyer's Hill Road. It is a soft, greenish, finely laminated shale, containing a soft limonitic clay, principally in seams; also rootlets. Only partially plastic. It lies over the Fredonia member of the Princeton (Ste. Genevieve) limestone, and is probably of that age. It is overlaid by Lafayette pebbles. Probably not of economic importance.

Bob Blakelee Shale.—Outcrops about two and six-tenths miles from Hampton, on the west side of Dooley's Bluff, where there are six feet of light brown shales, partially decomposed where exposed. They would probably be of value for a fertilizer. The material does not effervesce in acid. The section here, a part of the Birdsville formation, is as follows:

1. Sandstone from top.
2. Limestone, containing Pentremites pyriformis, Spirifer seminula, Productus, etc. ..... 28 ft.
3. Light brown shales..... 6 ft.
4. Covered, probably shales in part..... 24 ft. 6 in.
5. Limestone, grey..... 35 ft. 6 in.
6. Thin, shaly sandstone..... 5 ft. 6 in.
7. Covered to base of hill.

Coulter Clay.—In a drain on the R. E. Coulter land, about one and a half miles east of Golconda, in Livingston county, a greenish white, mottled with red, clay outcrops in close proximity to a sheer zone. It apparently resulted, in main, from the decomposition of Upper Birdsville shale. Is quite hard when dry and contains rootlets; somewhat plastic and slightly gritty. In part, contains admixed sandstone fragments. Extent not known.

Cossie Clay.—A greyish-white plastic clay, yellowish in part from limonite staining; is gritty and contains rootlets. Brought to the writer by Mr. Cossie, from his land a half mile out the Antioch Road after leaving the Carrsville-Hampton Road. Said to be found in a drain. Surface formation is Upper Birdsville.

* See note by J. H. G. on page 141.

Calcareous Shale.—About one hundred and fifty yards east of the Carrsville-Hampton Road, near where the road forks going to Antioch. It rests upon an Upper Birdsville limestone, and sandstone lies above it. It is a gray calcareous shale, disintegrated by roots and weathering. Probably of value as a fertilizer.

S. M. Wilson Shale.—Just south of where Dry Fork enters Powell creek, on S. M. Wilson's land, in Livingston county, is an outcrop of umbery shales, highly folded in close proximity to a fault and of St. Louis age. These shales vary much in character and probably are not of economic value.

Baxter Clays.—About two miles northwest of Salem, in Livingston county, on Mr. Baxter's land, specimens of three clays were collected. One of these was found in small pockets in sandstone conglomerate, resulting probably from the decomposition of the conglomerate in place. The conglomerate has quite a number of fossil plant impressions scattered through it. The clay is a gritty, somewhat micaceous, plastic clay, and is iron-stained where weathered. Does not occur in quantity. The second specimen was collected from a drain lower down the ridge and is probably a residual clay, from upper Birdsville limestone and shale decomposition, which has been deposited but a short distance from its source. It is a somewhat limonitic, highly calcareous clay, nor far from marl in nature. It is not gritty, but slightly plastic and fine grained. This is secured about sixty feet below the base of the Conglomerate. This clay, if in quantity, would probably be of value for fertilizer. The third is a yellow calcareous clay, seamed with purple seams, also calcareous. This is secured about twenty feet below the Conglomerate.

Howard Damron Shales.—Outcrops two and three-quarter miles southeast of Lola, near the county line in Livingston. They are light green shales mixed with some purple, of Upper Birdsville age, resting upon limestones and capped by sandstone shales. They are plastic and non-calcareous.

Simpkins Shale.—This occurs about three-quarters of a mile from Amis bridge, on Claylick creek, in Crittenden county. Occurs at an elevation of about 210 feet above the creek.

Clays and Shales Suitable for Paints.

There occur on the Carrsville-Antioch Road two outcrops of maroon-colored clay or partially decomposed shale. Both of these are probably of value for paints. The first is about one-half mile from the Carrsville-Hampton Road, on the Cossie land. Here it is dark maroon, with some yellow through it. It occurs in shale outcrop above heavy Upper Birdsville cherts, and above it are boulders of Upper Birdsville sandstone, limestones and sandstone conglomerate. The second occurrence is on Albert Slessor's land, a short distance from where old Antioch church stood, and outcrops in the west fork of Buck creek near its head. It is maroon in color and contains a few limonitic spots. Above it, on the east, quartzose sandstone boulders are found, while a large outcrop of sandstone conglomerate occurs above it on the west. The thickness of neither this nor the former clay was determinable, but both are probably a continuation of the same bed.

On the J. H. Vaughn land, four hundred yards to the right of the Greens Ferry Road, about four miles from Salem, a purplish maroon, with some green, shale is found. It is also an Upper Birdsville shale. The shale has been cut in two small prospect holes, ten to twelve feet deep, and is about five feet thick. Green shale is secured below the maroon.

Deep red clays, also suitable for paints, may be found in quantity in a number of places in Crittenden, Livingston and Caldwell counties. For the most part they are similar to the clays or lower layer laterites occurring above the St. Louis and Princeton (Ste. Genevieve), although the former are usually the darkest. Red clays of value for this purpose also occur in some of the other formations.

A bed of deep red clay occurs at the foot of the hill at the end of Mill street, in Smithland. It is four feet thick and is overlaid by a little gravel and brown loam. A bed, beneath the brown loam, also caps the hill at the cemetery, more sandy in character and not so deep in color. It is about five and a half feet thick and of Lafayette age.

Another bed occurs on the place of T. J. Rappolee, of Smithland, on Bissell's Bluff, in Livingston. Where opened, it

showed nine feet thick and was permeated by thin streaks of a bluish plastic clay.

Clays of a pretty green color occur in the Birdsville, and are well exposed in a number of localities, notably in the road three miles north of Smithland, and on the Lemon place, on Champion Hill, a mile or more northeast of Old Salem church.

A bed of plastic clay, light blue, occurs in a ravine on the old J. C. Miller place, but not in large amount, in the southern part of Livingston county, a few miles north of Gum Spring church.

Marls and Marly Clays and Shales.

Besides such of these as have been mentioned above, the following may be noted. Birdsville gray, green and olive colored marls and shales, which can be used not only for paints, but for fertilizers for impoverished lands. These are in many instances identical with the Leitchfield marls of Grayson county, which have been used also in the manufacture of cements proven to be equal to the Portland.

Among Livingston localities may be noted the following: In the road on Champion Hill, in front of Lemon's house; three miles north of Smithland, where the road to Dyer's Hill passes two ledges of rock, the marl occurs just beneath the road; and to the hillside to the east of the road leading south from Smithland to Threlkeld's bluff. The first is most accessible.

An occurrence in Crittenden that may be mentioned is found in the thirty-foot prospect shaft, sixty feet northeast of the cribbed shaft, on the secondary fault at the Givens Mines. The north wall consists of greenish and black shales and thin-bedded Middle or Upper Birdsville Limestone. The greenish shale is very high in lime, and seems to occur in quantity.

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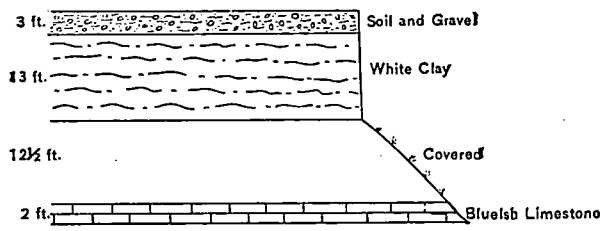
*_The J. E. Williamson Place_, Livingston county.—Note by J. H. Gardner: This land, owned by Mr. J. E. Williamson, of Paducah, is about two miles north of Grand Rivers and half a mile east of Gravel Switch. Here there is an exposure of beautiful white clay. The deposit is of comparatively recent formation, belonging to the Quaternary period, which covered the area of Kentucky west of the Cumberland and Tennessee rivers, and at some places is found crossing those rivers. The clay is betwen the two rivers.

At the exposure, which is along a bold ridge, a shaft had been sunk, but it had become filled before the examination was made. According to information given by Mr. Williamson, the shaft was over thirteen feet deep

and did not pierce the entire thickness of the deposit. Following is the section at the exposure:



This will probably prove to be a valuable deposit. The horizontal extent of the bed could not well be determined, because of timber growth around the ridge in which the clay is exposed.

The following analyses, made for the Survey by Burk & Lyon, indicate a relatively pure refractory clay of high quality:

	Per cent.
Hygroscopic moisture	0.50
Combined water	3.81
Silica	83.47
Alumina	8.20
Ferric oxide	1.16
Lime	0.69
Magnesia	0.12
Potash and soda	0.74
Titanium dioxide	0.83
Sulphur trioxide	0.28
	99.80

The rational analysis is:

Clay substance	33.03
Quartz	64.43
Feldspathic detritus	2.54
	100.00

PART II.

SILURIAN CLAYS,

WITH NOTES ON CLAYS OF THE WAVERLY AND IRVINE FORMATIONS.

Being Extracts from Part II, of a "Report on Silurian, Devonian, and Irvine Formations of East Central Kentucky, with an Account of Their Clays and Limestones," forming Bulletin No. 7.

By AUG. F. FOERSTE.

PREFATORY.

In order that as much as possible of the available information concerning our clays may be presented in a single bulletin, the following extracts from Part II. of the recently completed report on the Silurian, Devonian, and Irvine Formations of East Central Kentucky, by Prof. Aug. F. Foerste, assistant geologist, are included in this bulletin. Prof. Foerste's complete report is profusely illustrated with plates and maps, and in the economic section, of which these extracts form only a small part, not only the clays but the limestones and other economic values of the formations described are discussed. Necessarily, one must consult the complete report in order to intelligently study and trace the deposits here briefly described. It is printed as Bulletin No. 7.

It will be observed that in the arrangement of his text, Professor Foerste presents first a series of analyses, with descriptive notes, and then follows with a discussion of the possible uses of the materials.

Irvine formation is a name used by Mr. Marius R. Campbell, in his report on the Richmond quadrangle, for deposits of "unconsolidated sand, gravel, and clay, which originally covered the intermediate valley of the Kentucky river near the eastern edge of this (Richmond) quadrangle, but which are now found capping the river hills—the few remnants of what was once an extensive and continuous surface." He provisionally assigns the deposits to the "closing stages of the Neocene period." The formation is named from the town of Irvine. (Richmond Folio, U. S. Geo. Sur.)

In order that other geological references may be understood, the following table is given, showing the classification presented by Professor Foerste in the report named above.

C. J. NORWOOD,
State Geologist.

Table of Formations.

PREPARED BY PROF. AUG. F. FOERSTE.

	DIVISIONS.		BEDS.
Mississippian	Subdivisions not given, with exception of the lowest layer.		Linietta Clay (*at base of Waverly Series.*) *Phosphatic nodules.*
Devonian.	Ohio Shale. (*Known as the New Albany Shale in Indiana. Also called Devonian Black Shale.*)		Cleveland Shale. Chagrin Formation. Huron Shale.
	Devonian Limestone. (*Known as Corniferous Limestone in former reports. Possibly may include other strata than the Columbus Limestone.*)		*Duffin layer.* Columbus Limestone. (Equivalent to the Jeffersonville Limestone, and possibly also in part to the Sellersburg Limestone, in Indiana.) *Layer with fish plates and teeth.*
Silurian.	Crab Orchard division of the Silurian. (*Lower part of Niagaran division.*)	Alger formation.	Estill Clay, Waco Limestone, } Flades Clay. Lulbegrud Clay.
		Indian Fields formation.	Oldham Limestone. Plum Creek Clay.
	Brassfield division (*Clinton*).		Brassfield Limestone.
Ordovician.	Subdivisions not given in this table.		

SILURIAN, WAVERLY AND IRVINE CLAYS.

BY AUG. F. FOERSTE.

1. ANALYSES.

Most of the following analyses have been made for the present Survey, but several are appended which were made for the earlier surveys; as far as is possible from the information at hand, the geological positions of the samples collected by the latter are indicated in accordance with the revised classification.

2598.—Clay. From Panola, along Oldham branch, southeast of the railroad station; Madison county.

Geological position: Plum creek clay. A five-foot clay layer at the base of the Crab Orchard bed, immediately above the Brassfield or Clinton limestones. Collected by A. F. Foerste, 1904.

Analysis, sample air dried:

	Per cent.
Moisture	2.45
Ignition (combined water, etc.)	9.94
Silica	49.90
Alumina	18.15
Ferric oxide	5.57
Lime	4.02
Magnesia	3.32
Potash	5.32
Soda	0.33
Titanium dioxide	0.93
Sulphates	Trace
Total	99.93

2600.—Clay. From Irvine, along the road an eighth of a mile north of Estill Springs, and an eighth of a mile south of James Harris; Estill county.

Geological position: Lulbegrud clay, collected from two to thirteen feet below the massive two-foot layer which forms the base of the Waco formation. This is the middle clay of the Crab Orchard bed. Collected by A. F. Foerste, 1904.

Analysis, sample air dried:

	Per cent.
Moisture	1.98
Ignition (combined water, etc.)	6.12
Silica	58.82
Alumina	18.14
Ferric oxide	4.83
Lime	0.91
Magnesia	1.74
Potash	4.71
Soda	0.36
Titanium dioxide	1.25
Sulphur trioxide	0.12
Total	98.98

2187.—Clay shale or indurated clay. On the hill two hundred yards north of the home of Dr. Freeman. Two miles southeast of Bobtown, on the east side of the Big Hill pike, north of Joe Lick creek.

Geological position: Collected by John R. Procter, and stated by him to occur beneath the Corniferous limestone. The bed is six or more feet thick, and contains gypsum. Locality: R-S-21. Probably belongs to the Lulbegrud clay division of the Crab Orchard bed.

Generally in thin, soft, irregular laminae, of a light olive-gray color, irregularly varied with brownish yellow or ochreous. It contains gypsum in irregular crystals between some of the laminae. It is quite plastic with water. Burns quite hard, to a handsome light brick color.

Analysis, dried at 212 degrees F.:

	Per cent.
Combined water, carbonic acid, and loss	5.871
Silica	48.780
Alumina	17.320
Iron peroxide	3.240
Lime sulphate	19.285
Magnesia	0.496
Potash	4.768
Soda	0.240

2170.—Indurated clay. From the farm of C. L. Searcy, near Elliston, west of Waco two miles; Madison county.

Geological position: Collected by John R. Procter and stat-

ed by him to occur beneath the Corniferous limestone and to form a bed ten or more feet thick, and to make good soil. At Waco the base of the great mass of clays forming the Estill clay of the Crab Orchard series occurs below the Devonian limestone. It may be that the base of this upper clay is present also on the Searcy farm, although this clay is known to thin out westward.

Analysis, sample dried at 212 degrees F.:

	Per cent.
Combined water and loss	4.147
Silica	62.580
Alumina	22.940
Iron peroxide	3.760
Lime	0.560
Magnesia	0.425
Potash	5.280
Soda	0.308

2599.—Clay. From Panola, at the railroad cut east of the station.

Geological position: From the upper clay of the Crab Orchard bed, forming the main body of clays above the Waco horizon. Estill clay. Collected by A. F. Foerste, 1904.

Analysis, air dried:

Moisture	2.20
Ignition (combined water, etc.)	7.80
Silica	54.33
Alumina	19.44
Ferric oxide	5.00
Lime	1.88
Magnesia	2.22
Potash	5.15
Soda	0.31
Titanium dioxide	1.13
Sulphur trioxide	0.39
Total	99.85

2601.—Clay. From Irvine, on the hillside northwest of the home of James F. Harris, one mile north of town; Estill county.

Geological position: The upper or chief body of clay in the Crab Orchard bed, overlying the Waco horizon. The speci-

mens analyzed were a mixture of clays collected between twenty-seven and fifty-seven feet above the two-foot layer of limestone which forms the base of the Waco horizon. Estill clay. Collected by A. F. Foerste, 1904.

Analysis, sample air dried:

	Per cent.
Moisture	2.13
Ignition (combined water, carbon dioxide, etc.)	7.26
Silica	55.25
Alumina	20.79
Ferric oxide	4.40
Lime	1.51
Magnesia	1.04
Potash	4.95
Soda	0.41
Titanium dioxide	1.16
Sulphates	Trace
Total	98.90

2619.—Crab Orchard. At the exposure south of the roadside well at the north end of the grounds belonging to the Crab Orchard Springs hotel, one mile north of the station, and a quarter of a mile south of Dix river.

Geological position: From the upper or chief clay layer forming the greater part of the Crab Orchard bed. Collected from the upper part of the section, fifty-five feet thick. These clays belong to the Estill bed, above the Waco horizon. Collected by A. F. Foerste, 1904.

Analysis, sample air dried:

	Per cent.
Moisture	1.69
Ignition (combined water, carbon dioxide, etc.)	7.86
Silica	54.48
Alumina	18.90
Ferric oxide	5.64
Lime	2.50
Magnesia	1.71
Potash	4.67
Soda (traces of lithia)	0.38
Titanium dioxide	1.12
Sulphates and phosphates	Traces
Total	98.95

2186.—Clay shale. On the road near Anderson Lake's house, three hundred yards west of Drowning creek, two miles southwest of Panola, a mile and a half northwest of Combs.

Geological position: Collected by John R. Procter, from the "Niagara Group." Either from the Lulbegrud clay division of the Crab Orchard bed, or from the Estill clay of this series, above the Waco limestones; probably the latter. Locality, R-SE-21.

An olive-gray and brownish gray, somewhat firm shale, mottled in parts. Quite plastic with water when powdered. Calcines to a light brick color.

Analysis, dried at 212 degrees F.:

	Per cent.
Combined water, carbonic acid, and loss	16.221
Silica	42.300
Alumina	20.840
Iron peroxide	4.120
Lime	13.320
Magnesia	0.461
Potash	2.387
Soda	0.351
Total	100.000

2. Possible Uses of Silurian Clays for the Manufacture of Clay Products.

If attention be confined to the clays investigated by the writer, a considerable similarity in the chemical composition of the clays from the different horizons is noticed. The percentage of silica in these samples varies from 50 to 58 per cent.; that of alumina, between 18 and 21 per cent.; that of ferric oxide, between 4.5 to 5.5 per cent.; that of potash, between 4.6 and 5.3 per cent.; that of soda, between 0.3 and 0.4 per cent. The percentage of lime and magnesia, however, is much more variable, the proportion of these substances being greatest in the case of the sample of Plum creek clay.

These samples of clay were selected with special reference to their availability for commercial purposes. Considerable care was taken to secure samples from localities where large quantities of these clays were available and to select the ma-

terial in such a manner that an analysis of the mixture would give a very fair idea of the general characteristics of the clay as they would appear under ordinary methods of manipulation.

From these preceding analyses it is evident, of course, that they have no value as fireclays. They contain too much of each one of the fluxing materials—potash and soda, ferric oxide, and lime and magnesia. On this account they melt at too low a temperature and hence will not serve for brick intended to stand a high temperature.

They also have no value as stoneware clays, as the following table, giving the range of the percentage of the various constituents of good typical stoneware clays will show:

	Maximum	Minimum	Average of 8 analyses
Silica	72.10	45.00	64.08
Alumina	38.24	19.08	23.86
Ferric oxide	1.50	0.96	1.23
Lime	1.70	0.00	0.78
Magnesia	0.68	0.11	0.40
Soda	Trace	0.00	Trace
Potash	2.42	0.15	1.48
Oxide of lithium, with some soda	0.02	Trace	Trace
Titanium oxide	1.30	0.29	0.46
Water	14.80	6.25	7.78

A comparison of the analyses of the Silurian clays with this table indicates that the Silurian clays contain too great a percentage of fluxes. In place of a maximum of 2.4 per cent. of alkalies, as in good stoneware clays, the Silurian clays contain from 5 to 5.6 per cent. of potash and soda. In place of a maximum of 3.9 for the total quantity of ferric oxide, lime and magnesia, the Silurian clays contain between 7 and 13 per cent.

As far as may be determined from the analyses, these Silurian clays should be almost ideal for the average run of vitrified wares. This is well brought out by the following table, which indicates the range of variation of the principal constituents in

a number of clays which have been found to be of value for these purposes.

	Maximum	Minimum	Average
Silica	75.00	49.00	56.00
Alumina	25.00	11.00	20.50
Ferric oxide	9.00	2.00	6.70
Lime	3.50	0.20	1.20
Magnesia	3.00	0.10	1.40
Soda and potash	5.50	1.00	3.70
Loss on ignition	13.00	3.00	7.00

In the Silurian clays here discussed, the percentage of silica varies between 54 and 59 per cent., except in the case of the Plum creek clay, where the proportion of silica is nearly at a minimum. The percentage of alumina varies between 18 and 21; that of ferric oxide, between 4.5 and 5.5 per cent. The percentage of lime exceeds the maximum in the case of the Plum creek clay, but varies between 0.9 and 2.5 per cent. in the other cases. The magnesium also is in excess in the case of the Plum creek clay. The alkalies, potash and soda, on the contrary, are fairly high in the case of all of the clays (from 5 to 5.6 per cent).

Clays of this description are used for sewer pipe, paving brick and other purposes, where the materials do not have to withstand high temperatures. Clays of this class should be fine-grained and plastic, and should vitrify at temperatures as low as 2,130 degrees to 2,210 degrees F. On this account the clays should contain a considerable amount of fluxing materials. However, to prevent complete fusion, there should not be much potash and soda, since in these cases there is frequently too little difference in temperature between the point of incipient fusion and that of complete fusion. The difference between these points should be about 150 degrees to 200 degrees F. apart, in order that the articles made from the clay may be raised to the temperature of incipient fusion or vitrification, without any danger of the temperature rising sufficiently to approach complete fusion, which, of course, would cause the articles formed from the clay to lose their shape, stick together, and become thoroughly valueless.

High-grade terra cotta work is now made from a mixture of fire-clays which burn to a buff color. The Silurian clays here

under discussion are not fire-clays, and they would not burn to a buff color. Clays containing 5 per cent. or more of iron burn to a deep cherry-red, unless under-burned, in which case the resulting ware loses in strength, and in fact may be worthless. There is no known reason, however, why the Silurian clays in question should not prove available for the lower grades of terra cotta.

On account of their large percentage of iron, these Silurian clays are not available for the manufacture of yellow and buff brick. They should, however, make excellent bricks of the common red variety. Brick clays should have a sufficient percentage of fluxes to reach incipient fusion at a little over 1,900 degrees F., and should burn hard at a temperature of not over 2,000 degrees F. The Silurian clays here discussed have not been tested as yet as to their fusibility. It is probable that a good quality of pressed brick might be made out of these clays, but the color would be deep red and the brick would not be as hard as the pressed bricks made of more refractory material.

The clay from the C. L. Searcy farm shows a distinctly higher percentage of silica, and a distinctly smaller per cent. of lime, magnesia and iron than the clays collected by the writer. The clays from the Dr. Freeman and Anderson Lake localities are notable chiefly for the large quantities of calcium which they contain. In the case of the clay from the Dr. Freeman locality, the calcium is determined in the form of calcium sulphate, indicating the presence of considerable quantities of gypsum.

The use of the Crab Orchard clays for the purpose of manufacturing artificial cements should receive further attention. At present many of these artificial cements enter the market under the name of Portland cements. Various materials may be used in the manufacture of these cements. Among these are marl mixed with clay, limestone mixed with clay, argillaceous limestone mixed with pure limestone, limestone mixed with shale, limestone mixed with the calcareous waste left from the manufacture of caustic soda.

In order to give some idea of the sort of mixtures of limestone and clay that have proved to be of practical utility in the manufacture of Portland cements, the following analyses have been added. The first column in each table gives the ingredients of the limestone entering into the mixture, the second col-

umn gives the ingredients in the clay used, and the third gives the composition of the finished product, the so-called Portland cement.

Analyses of materials used by the Catskill Cement Company, at Smith's Landing, in Greene county, New York, and published by the New York Survey:

	Limestone	Clay	Resulting Cement
Silica	1.54	61.92	22.48
Alumina	0.39	16.58	6.52
Ferric oxide	1.04	7.84	4.46
Lime	53.87	2.01	62.93
Magnesia	0.52	1.58	1.48
Alkalies	.....	3.64	.....
Sulphur trioxide	.....	Trace	1.30

The following analyses were published from an investigation of materials used by the Glens Falls Portland Cement Company, in Warren county, New York:

	Limestone	Clay	Resulting Cement
Silica	3.30	55.27	21.50
Alumina, ferric oxide	1.30	28.15	10.50
Lime	52.15	5.84	63.50
Magnesia	1.58	2.25	1.80
Alkalies	.....	.....	0.40
Sulphur trioxide	0.30	0.12	1.50
Carbon dioxide	40.98	.....	.....
Organic matter and water	8.37	.....	.....

In the latter case the limestone and clay are dried and crushed separately. After being weighed on automatic scales, the materials are mixed dry and reduced to fine powder. This powder is then fed into wet mixers, where sufficient water is added to allow the mixture to be made up into bricks. The bricks are dried in tunnels heated by waste heat from the boilers, blowers being used to drive the heat through the tunnels. After drying, the bricks are burned in kilns, and the clinkers resulting

from the bricks are reduced to powder in mills constructed for this purpose. The powder is the finished product, the Portland cement.

The essentials in the manufacture of Portland cements are lime and silica. The lime is furnished by limestone or marl, and the silica is furnished by the clay. In burning, the lime and silica unite so as to form the compound $3CaO.SiO_2$, called tricalcic silicate. This compound, in large measure, supplies the hydraulic properties of the cements. The ideal Portland cement would consist, therefore, exclusively of tricalcic silicate, and would be composed entirely of lime and silica in the proportion of 73.6 per cent. of lime and 26.4 per cent. of silica.

Such an ideal cement, however, can not be prepared at present under conditions such as to make it a commercial product, since the heat required to cause pure lime and silica to unite can not be attained in any commercially useful kiln. In actual practice, therefore, it becomes necessary to select materials which, in addition to lime and silica, contain also other ingredients which will serve as a flux. The most important of these ingredients are alumina and ferric oxide, and when present in notable percentages they lower the temperature at which lime and silica will combine to a considerable degree. However, as the percentage of alumina and ferric oxide increases, the strength of the Portland cement decreases, so that considerable judgment must be used in the selection of materials.

In burning, the alumina is believed to combine with the lime so as to form dicalcic aluminate, $2CaO.SiO_2$, and there is a possibility of a similar combination in the case of ferric oxide, forming the compound $2CaO.Fe_2O_3$. Owing to the relatively small percentage of ferric oxide in the materials used for Portland cements, it may be considered as producing about the same effect as alumina, and the two may be calculated together.

Owing to the necessity of having the fluxing materials, alumina and ferric oxide, present, in addition to the lime and silica, the necessary elements of Portland cement, before burning, may be said to be about 75 per cent. of carbonate of lime, and 20 per cent. of silica, alumina, and iron taken together. The remaining 5 per cent. will include the magnesium carbonate, alkalies, and sulphur compounds which may be present. Of the essential ingredients, the lime is usually furnished by

the limestone, while the silica, alumina, and ferric oxide are supplied by the clay.

Some of the impurities found in the unburned materials may be regarded as useful to the cement. One of these is calcium sulphate, which, if present only in small quantities, retards the set of the cement. Magnesium carbonate is an undesirable impurity in the unburned mixture, and should form less than 3.5 per cent. of the latter.

For use as Portland cements the clays should carry not less than 55 per cent. of silica, and preferably from 60 to 70 per cent. The alumina and ferric oxide calculated together should not amount to more than one-half of the percentage of the silica. The value of the clay is greater in proportion as the ratio of its ingredients approaches $Al_2O_3+Fe_2O_3 = \frac{SiO_2}{8}$. The percentage of magnesia and alkalies should be low, preferably not over 3 per cent.

From these statements it is seen that there is a possibility of the usefulness of the Crab Orchard clays for Portland cement, but that its usefulness can not be determined definitely until the composition of the available limestones is known, and the latter has not yet been determined.

Lower Waverly Beds.

1. Linietta or Bedford Clay Shales.

At the base of the Waverly series of strata there is a great mass of clays, here called the Linietta clay, which occupies about the same horizon as the Bedford clay of Ohio, but which may include a greater part of the Waverly series. The analyses of these clays are fairly represented by those cited below.

2597.—Linietta or Bedford clay from Blue Lick, Madison county. From Berea, 1.5 miles northeast on Kingston pike, then 1.5 miles E. to junction with Blue Lick pike; southwest of road corner.

Geological position: From the base of the Waverly to forty feet above the base. Collected by A. F. Foerste, 1904.

Analysis of air-dried sample:

	Per cent.
Moisture	1.75
Ignition (combined water, etc.)	4.29
Silica	65.58
Alumina	16.00
Ferric oxide	5.21
Lime	0.03
Magnesia	1.25
Potash	3.89
Soda	0.82
Titanium dioxide	1.13
Sulphates and phosphates	Traces
Total	99.95

2499.—Clay. On the land of John Pigg, three miles northeast of Berea, two miles south of Bobtown, near the road from Berea to Bobton, at the Blue Lick. Locality: R-S-8.

Geological position: Linietta or Bedford clay shale at base of the Waverly series. Collected by Moritz Fischer, August 16, 1884.

Analysis of air-dried sample:

	Per cent.
Hygroscopic moisture	1.030
Combined water and loss	2.947
Silica	68.440
Alumina and iron oxide	20.180
Lime carbonate	0.144
Magnesia carbonate	2.860
Potash	3.678
Soda	0.740
Phosphoric acid (P_2O_5)	A trace
Total	100.000

Pulverized and kneaded with water, it would be plastic enough to be used for common pottery-ware.

2618.—Analysis of clay, Junction City, Boyle county, Ky.

Geological position: Linietta or Bedford clay at base of Waverly series. Blue Lick, northwest of Linietta Springs, northwest of Junction City about one-half mile. A. F. Foerste, 1904.

Analysis of air-dried sample:

	Per cent.
Moisture	1.35
Ignition (combined water, etc.)	4.85
Silica	62.44
Alumina	17.87
Ferric oxide	6.31
Lime	0.18
Magnesia	1.18
Potash	3.52
Soda	0.77
Titanium dioxide	1.04
Sulphur trioxide	0.19
Total	99.70

1873.—Clay. From the head waters of Green river, on the land of Thomas W. Varnon. Bed two to four feet from the surface, and said to be forty-two to forty-five feet thick; resting on Black Shale which is fifty feet thick. Salt water is found by boring at a depth of eighty-four feet, and some little petroleum in the sandstone. Collected by Senator Varnon.

Geological position: From the Linietta or Bedford clay shale, forming the base of the Waverly series.

Clay imperfectly laminated, of a dark olive-gray color. Burns to a gray-buff color. The considerable proportions of the iron oxide, lime, potash, and soda prevent this clay from being refractory in the fire, but, while it is therefore unfit for the manufacture of firebrick, it will yet answer well for ordinary pottery, terra cotta work and tiles.

Analysis, dried at 212 degrees F.:

	Per cent.
Water and loss	5.705
Silica	61.580
Alumina	23.946
Iron protoxide	5.814
Phosphoric acid	Not determined
Lime	0.201
Magnesia	0.850
Potash	1.542
Soda	0.362
Total	100.000

As compared with the Crab Orchard clay, these clays at the base of the Waverly series contain more silica, about the same amount of alumina and iron, and a less quantity of lime, magnesia, and potash. These clays contain too much iron to be serviceable as stoneware clays. They contain, however, enough iron and alkalis, and are sufficiently low in lime and magnesia to make excellent clays for vitrified ware: paving brick, sewer pipe, and the like. They will burn to a cherry red color, and would serve also for the manufacture of ordinary brick. Owing to the larger percentage of silica, the Linietta or Bedford clays should be more serviceable than the Crab Orchard clay for the manufacture of Portland cement. The clay from the Blue Lick locality, for example, conforms quite closely to the formula that the sum of the alumina and the iron oxide shall equal about one-third of the silica, and the requirement that the silica shall equal at least 55 per cent., and preferably should be between 60 and 70 per cent. The difficulty arises in finding a suitable limestone within a convenient distance of the Linietta clay deposits.

2. Upper Layers of the Waverly Series.

No attempt has been made to study the upper layers of the Waverly series. The following analysis of a sample from a clay member is presented:

2498.—Plastic clay. From the land of Gordon Glasgow, on the slope of Bear Mountain, three miles southeast of Berea, Madison county.

Geological position: Clay in the Waverly series, near the Conglomerate. This is probably a clay member of the Pennington shale, near the Rockcastle conglomerate. Collected by Moritz Fischer, July 1, 1884.

A light gray, plastic clay. Calcines to a light reddish color. This clay could be used for the manufacture of various kinds of common pottery ware, terra cotta products, and the like.

Analysis of air-dried sample:

	Per cent.
Water and loss	20.014
Silica	48.000
Alumina	18.380
Iron peroxide	3.900
Lime carbonate	1.600
Magnesia carbonate	4.033
Potash	3.797
Soda	0.276
	100.000

THE IRVINE CLAYS.

Probably no class of clays in the central parts of Kentucky has aroused a wider interest for a langer time than those from the Irvine formation in various parts of Madison county. From no area of similar small size have we as many analyses. This is due to the fact that at an early date a fairly extensive production of common stoneware was founded upon the use of this clay, and that this stoneware industry is still in existence.

Stoneware differs from common earthenware chiefly in the fact that earthenware is burned merely until it reaches the stage of incipient vitrification, but remains porous, while in the case of stoneware the clay is burned to vitrification, so that the body of the ware becomes impervious to moisture. The color of the body may be reddish, buff, or bluish black, but this color frequently is concealed by a coating of salt glaze or slip. Stoneware is made usually from refractory or semi-refractory clays, the best results often being obtained by mixing different clays. One of the clays is used to supply stiffness to the body in burning, while the other supplies the fluxing qualities and serves to bind the ware together. The fusible impurities must be of such a character as to cause the body to attain only a state of incipient fusion while the slip or glaze at the same temperature will melt.

When the ratio of alumina to ferric oxide equals 7 to 1, the resulting stoneware is not colored red by the ferric oxide, but takes on a yellowish color, which becomes yellowish-white or nearly white as this ratio approaches 13 to 1. Clays of this kind could be used also for the manufacture of light or buff brick.

Chemical analyses usually show the following range of variation:

	Maximum	Minimum	Average of 8 analyses
Silica	72.10	45.00	64.08
Alumina	38.24	19.08	23.86
Ferric oxide	1.50	0.96	1.23
Lime	1.70	0.00	0.78
Magnesia	0.68	0.11	0.40
Soda	Trace	0.00	Trace
Potash	2.42	0.15	1.48
Water	14.80	6.25	7.78

Among the earlier analyses of the stoneware clays of Madison county are the following:

946.—Potter's clay. Four miles northwest of Irvine, on the Richmond pike. Light buff-gray with stratified lines of reddish. Appears to be principally fine quartzose sand with a few minute sparkling specks of mica.

Geological position: Irvine formation.

	Per cent.
Water, expelled at red heat	4.400
Silica	71.780
Alumina	17.580
Iron oxide	2.420
Lime	None
Magnesia	0.547
Potash	2.271
Soda	0.322
Sulphuric acid	0.112
Loss	0.568

1122.—Potter's clay, near Waco.

Geological position: Irvine formation.

Analysis:

	Per cent.
Water, expelled at red heat	6.140
Silica	62.580
Alumina	21.980
Iron oxide	4.780
Brown oxide of manganese	Trace
Phosphoric acid	Not Est.
Sulphuric acid	0.234
Lime	Trace
Magnesia	1.276
Potash	2.607
Soda	0.500

In sample No. 946, the ratio of alumina to ferric oxide is about 7 to 1, and the clay should burn to a buff color. The percentage of silica is rather high, and the clay should prove more refractory than sample No. 1122. In the latter case the ratio of the alumina to ferric oxide is about 5 to 1, and the color of the burned clay should be darker.

Two additional analyses of the potter's clay at Waco were published in 1877.

1876*a*.—Potter's clay, quality No. 1. Light gray, soft clay.

1876*b*.—Potter's clay, quality No. 2. Of a bluish-gray color.

Both clays from the neighborhood of Waco. These are good clays for ordinary stoneware.

Analyses, dried at 212 degrees F.:

	1876*a*	1876*b*
Combined water and loss	7.020	10.531
Silica	59.976	56.960
Alumina, iron and manganese oxide, and phosphoric acid	27.640	28.740
Lime Carbonate	0.280	0.200
Magnesia	0.606	0.752
Potash	3.931	2.502
Soda	0.547	0.315
Total	100.000	100.000

These samples do not differ greatly from No. 1122, although the percentage of silica is less. Possibly the inferior quality of the sample said to be of quality No. 2 was due to its vitrifying at a lower temperature, due to a smaller percentage of silica and a larger percentage of iron.

In 1879 two additional analyses were published, presumably from clay used for the manufacture of stoneware. Bybeetown is now known as Portland, and is still the seat of stoneware manufacture. The Oldham locality is believed to have been on the Bybeetown side of Waco.

2168.—Clay. From near Bybeetown or Portwood. Milton Barlow. Bed four feet thick, overlying Black Shale.

Geological position: Probably from the Irvine formation. Collected by John R. Procter.

Clay of a light, warm drab-gray color. Irregularly and imperfectly laminated. Quite plastic. Burns to a delicate light reddish-cream color, nearly white.

2169.—Clay of workable thickness; on the road leading from Waco to R. Oldham; about a mile and a half from Waco.

Geological position: Collected by John R. Procter, and stated by him to occur probably below the Corniferous limestone. The exact locality not being known, this statement can not be verified, but, in this area, plastic clays with a very small percentage of lime are not known in Silurian formations.

A compact clay, generally of a light, olive-gray color, stained irregularly with ochreous and ferruginous. Quite plastic. Calcines quite hard, to a handsome light brick color.

Analysis, sample dried at 212 degrees F.:

	No. 2168	No. 2169
Water and loss	6.973	5.166
Silica	62.560	64.566
Alumina	24.780	20.160
Iron peroxide	1.800	4.200
Lime	A trace	0.213
Magnesia	0.317	0.641
Potash	3.276	5.054
Soda	0.294	Not Est.
Total	100.000	100.000

Regarding these clays, Dr. Robert Peter, then chemist of the Survey, made the following remarks:

"These are good plastic clays for the manufacture of ordinary pottery ware, as well as for ornamental articles of terra cotta, for which they are adapted because of the pleasing tints which they assume on calcination. They owe these tints to their considerable proportion of iron oxide, which, together with their large proportion of potash, renders them unavailable as fire-clays. This very circumstance, however, may fit them for stone-

ware and for superior kinds of hard burnt, semi-fused, ornamental pottery in the hands of skillful workmen and artists."

The ratio of alumina to ferric oxide in sample No. 2168 is about 13 to 1, and the clay should burn to a nearly white color. In sample No. 2169, this ratio is about 5 to 1, and the clay should burn to a distinctly brick-red color. The percentage of potash is large, and the clay should flux at a distinctly lower temperature than any so far mentioned. This should cause it to be regarded as an inferior clay.

In 1884, the following analyses were published, showing that the interest in stoneware clay still focused around Bybeetown and Waco, in Madison county.

2496.—Clay. From the land of James Walker Lewis, two miles southeast of Bobtown, about one hundred yards to the left of the Big Hill pike, almost opposite the blacksmith shop.

Geological position: Bed four to five feet thick, resting on Silurian clay shale. Sample of the upper ten inches. Collected by Moritz Fischer, June 21, 1884. The Silurian clay shale at this locality is the Lulbegrud clay division of the Crab Orchard bed. The overlying clay, of which the analysis is given, probably belongs to the Irvine formation. Locality: R-S-22.

A laminated clay or soft shale, of a light gray color on the exterior; darker colored and brownish-yellowish-gray in the interior.

2497.—Clay. From the same locality as the preceding. Sample from ten to twenty inches below the surface. Collected by Moritz Fischer.

Geological position: Apparently from the Irvine formation, but the large percentage of lime is more suggestive of Silurian clays.

Darker colored than the preceding; of a light olive-green color.

No doubt common pottery ware and terra cotta could be made of this clay, ground and properly tempered with water. It contains too much potash, lime and iron oxide for a fireclay.

Analyses of air-dried samples:

	No. 2496	No. 2497
Water, carbonic acid, and loss	8.091	15.548
Silica	59.000	42.560
Alumina and iron oxide	24.640	20.980
Lime	1.456	8.680
Magnesia	1.096	7.247
Potash	5.500	4.819
Soda	0.217	0.166
Titanic acid	.....	Trace
Total	100.000	100.000

Sample No. 2496 contains 20.68 per cent. of alumina and 3.96 per cent. of iron peroxide.

As compared with other clays from the Irvine formation, the percentage of lime in sample No. 2496 is rather high, and the same may be said of the percentage of magnesia and potash. In this respect the clay approaches some of the Crab Orchard clays. The ratio of alumina to ferric oxide is about 5 to 1, and the clay should burn to a light brick-red color. It should fuse at a much lower temperature than the potter's clays hitherto mentioned, with the exception perhaps of sample No. 2169. Sample No. 2497 is utterly at variance with any other clay known in this part of Kentucky. It has a low percentage of silica and a high percentage of lime and magnesia compared with the clays so far investigated. It should not prove sufficiently refractory to make a good stoneware clay. The age of these clays is not definitely known.

Several analyses have been made for the present Survey. The following analysis is taken from a sample of the clay used by the firm of D. Zittel & Son, manufacturers of common stoneware, about half a mile east of Waco. The clay is obtained from the McKinney farm, southeast of Waco.

2615.—Clay. Waco, Ky., on G. S. McKinney's land, Madison county, Ky.

Geological position: Irvine bed. Thickness, 3.5 to 5 feet. A. F. Foerste, 1904. From Waco, one-fourth mile S., one-fourth mile E.; pit on south side of road.

Analysis of air-dried sample:

	Per cent.
Moisture	2.27
Ignition (combined water, etc.)	5.85
Silica	63.76
Alumina	19.36
Ferric oxide	2.59
Lime	0.40
Magnesia	0.82
Potash	2.86
Soda	0.47
Titanium dioxide	1.25
Sulphuric anhydride	Trace
Total	99.63

In this case the ratio of the alumina to the ferric oxide is about 7.5 to 1, and the clay burns to a light buff color. It is used at present for jugs, jars, churns, and the like, but apparently might be made useful also for architectural terra cotta, chemical stoneware, clay pipes, and the like, although not very refractory clay. In this respect it is surpassed by the white clay from the Adams farm, next to be described. This clay contains more alumina and less ferric oxide, lime and magnesia. The percentage of alumina to ferric oxide is about 19 to 1, and the clay burns to a very light color. On this account it should be valuable for architectural terra cotta and for light-colored pressed bricks, especially for those which are artificially colored or speckled by the use of manganese or other metallic oxides.

2635.—White clay on the Adams farm, near Waco, Madison county. Color nearly white, banded in places with brown. Found at the same locality as No. 2636.

Geological position: Irvine bed. Collected by A. F. Foerste in 1904.

Analysis of air-dried sample:

	Per cent.
Moisture	1.60
Ignition (combined water and volatile matter)	6.74
Silica	61.00
Alumina	23.68
Ferric oxide	1.21
Lime	0.20
Magnesia	0.68

Potash	3.09
Soda	0.43
Titanium dioxide	1.39
Sulphur trioxide	Trace
Total	100.02

At present the Adams farm clay is used at the tiling factory, at Searcy station, in the manufacture of roofing tiles. It is mixed with the clay which comes from the immediate vicinity of the factory, and probably serves to bind the latter together. The following analysis indicates the nature of the resulting mixture, consisting chiefly of clay obtained from the pit at the factory.

2634.—Tiling factory clay. Obtained north of the factory at Searcy station, about a mile southeast of Moberly. The sample consisted of broken unburned roofing tiles. It was buff-colored and uniform in appearance.

Geological position: Irvine bed. Directly above the Devonian black shale. Collected by A. F. Foerste, in 1904.

Analysis of air-dried sample.

	Per cent.
Moisture	1.75
Ignition (combined water and volatile matter)	4.26
Silica	73.78
Alumina	13.23
Ferric oxide	1.24
Lime	0.54
Magnesia	0.82
Potash	2.27
Soda	0.50
Titanium dioxide	1.25
Sulphur trioxide	Trace
Totals	99.64

This clay mixture contains more silica and less alumina than any so far described. It is not used for stoneware, but only for roof tiling, drainage tiling, and brick. The roofing tiles are burned to a light red color, but those so far put out appear underburned.

The following analysis shows the nature of the clay used at the Searcy roofing-tile factory as fireclay.

2636.—Fire-clay used by Searcy at the roof-tiling works. Obtained from the Adams farm, near Waco, Madison county. Samples mostly in the state of coarse powder, with some friable lumps. Buff-colored, with some brown specks in the lumps. Found by going three-quarters of a mile north from Waco, then an eighth of a mile east, and finally, across a field, an eighth of a mile south, past a cabin.

Geological position: Irvine bed. Collected by A. F. Foerste, 1904.

Analysis, sample air-dried:

	Per cent.
Moisture	1.52
Ignition (combined water and volatile matter)	3.56
Silica	81.54
Alumina	9.36
Ferric oxide	1.17
Lime	0.10
Magnesia	0.39
Potash	0.56
Soda	0.29
Titanium dioxide	1.25
Sulphur trioxide	None
Total	99.74

The relatively small percentage of alumina should be noted. The point of incipient fusion of this clay has not been determined.

The following clay was analyzed for Mr. Searcy. It does not differ conspicuously from the stoneware clays previously cited. It probably belongs to the upper part of the Irvine formation, as far as may be determined from the analysis. No careful study was made of its position in the geological scale.

2616.—Alluvial clay. Waco, Madison county, Ky.

Geological position: Alluvial clay. 1⅛ or 1.12 miles east, then ¼ mile south of Waco, on Grinstead farm. Black clay. A. F. Foerste, 1904.

Analysis of air-dried sample:

	Per cent.
Moisture	1.72
Ignition (combined water, etc.)	6.38
Silica	65.82
Alumina	18.01
Ferric oxide	2.48
Lime	0.22
Magnesia	0.77
Potash	2.91
Soda	0.46
Titanium dioxide	1.25
Sulphur trioxide	Trace
Total	100.02

The next analysis gives the composition of the ordinary brick and tiling clay used by the Moberly Brick Company, and secured from the immediate vicinity of the plant, west of Moberly station. It contains a much larger percentage of ferric oxide than any clay here discussed, and evidently would not be useful for any other purpose that that for which it now is employed. It is chiefly an alluvial deposit.

2617.—Clay. Moberly, Ky., Madison county.

Geological position: Irvine formation. Used for brick and tile at the Moberly Brick Co. plant at Moberly.

Analysis, air-dried:

	Per cent.
Moisture	1.98
Ignition (combined water, etc.)	4.20
Silica	74.36
Alumina	7.79
Ferric oxide	6.78
Lime	0.14
Magnesia	0.53
Potash	1.59
Soda	0.49
Titanium dioxide	1.25
Sulphates and phosphates	Traces
Total	99.11

The Clay Industries of Madison County.

Only two stoneware potteries at present are in operation, one at Waco, and the other at Bybeetown or Portland.

The pottery half a mile east of Waco is known as the D. Zittel & Son pottery. They use the clay from the George McKinney farm, southeast of Waco. The clay bed varies in thickness from four to seven feet. In some parts of the pit the clay rests upon sand. In these cases it is considered better and will stand a little more fire. In other parts of the pit the clay rests upon the Black Shale, and then is believed to be less refractory. No reason for this difference can be noticed on examining the clay in the pit.

Albany slip clay mixed with red lead and manganese is used as a glaze. The materials are obtained from the Bauer Pottery Company, Louisville, Ky.

The articles made are as follows:

Jugs, in 1-quart, and ½, 1, 2, 3, 4, and 5-gallon sizes.

Jars, in 1-quart, and ½, 1, 2, 3, 4, 5, 6, 8, and 10-gallon sizes.

Fruit jugs, put up with lid so that they can be sealed. Used chiefly for keeping sorghum. Put up in 2, 3, 4, and 5-gallon sizes.

Fruit jars, with lid, in 1-quart and in ½ and 1-gallon sizes. Used chiefly for fruit jams.

Pitchers, in 1-quart, and ½, 1, and 2-gallon sizes.

Churns, in 2, 3, 4, 5, and 6-gallon sizes. Supplied with lid.

Milk pans, in ½, 1, and 2-gallon sizes.

Chambers, in ½ and 1-gallon sizes.

Flower pots, in 2, 3, 4, 5, 6, 7, 8, 10, 12, and 14-inch sizes.

The following analysis indicates the chemical composition of the Albany slip clay.

	Per cent.
Free silica and sand	38.58
Combined silica	17.02
Alumina	14.80
Ferric oxide	5.85
Manganic oxide	0.14
Lime	5.70

Magnesia	2.48
Potash	3.23
Soda	1.07
Phosphoric acid	0.15
Water	5.18
Moisture and carbonic acid	4.94
Total	99.14

This clay not only fuses at a low temperature, but also produces a glaze of uniform color, and one which does not crack. Its fusibility may be lowered by the admixture of various metal compounds, as indicated in the following recipe.

Albany slip clay	63.30 to 70	parts.
White lead	25.30 to 17	parts.
Flint	6.30 to 7	parts.
Oxide of iron	.72 td .79	parts.
Oxide and manganese	.56 to .61	parts.
Chromate of lead	1.27 to 1.40	parts.
Chromate of iron	.67 to .73	parts.
Oxide of zinc	1.88 to 2.07	parts.

At Bybeetown or Portland is located the pottery of J. E. Cornelison & Son. The clay is obtained on the road from Waco to Cobb Ferry, about a mile and a half east of the junction of this road with the road from Waco to Bybeetown. The pit is located northwest of the road corners, at which the road across Falling Brook joins the road from Waco to Cobb Ferry. The thickness of the clay bed in the clay pit averages about five feet. The clay overlies the Black Shale. The clay is brought to the shop and put in a ring pit. This ring pit usually consists of a circular tub, between twenty-five and thirty feet in diameter, three feet deep, and lined with boards. In this revolves an iron wheel about six feet in diameter, and so geared that it travels from the center of the tub to its sides and then back again toward the center. This breaks up the clay thoroughly and tempers the clay in about six hours. This tempering is called "pugging." The power used at the Bybeetown pottery is a single horse. The clay is taken from the pug tub to the cellar and there kept moist for further use.

The objects manufactured are chiefly jars, jugs and churns, in the following sizes:

Jars, 1 quart, ½, 1, 2, 3, 4, 5, 6, 8, 11 gallons.
Jugs, 1 quart, ½, 1, 2, 3, 4, 5, 6, 8, 10 gallons.
Churns, 2, 3, 4, 5, 6, 8 gallons.

The glaze used is a slip clay mixed with red lead and manganese. This is all stirred together, the slip clay being strained before mixing. The pottery is dipped into the mixture and dried before going to the kiln. The kiln used is a down-draft kiln, and coal is used as a fuel. The kiln is heated up slowly for about twenty-four hours and then raised to a white heat for twenty-four hours. A peep hole is left to enable the operator to examine the interior of the kiln, and the state of firing is determined chiefly by the color of the ware, although test pieces also are used. Whenever the glaze is good on these test pieces, the burning is considered sufficient. Then the kiln is allowed to cool for fifty hours. No Seger cones are used.

In addition to pottery, 4, 6, and 8-inch tiling also is manufactured.

At Searcy station, about a mile southeast of Moberly, the Lexington Tile Roof Company is situated. Here the Waco shingle tile is manufactured.

The chief clay used for this purpose is obtained directly north of the factory. At the pit about half a foot of soil is stripped off at the top, and the underlying clay layer, five feet thick, is taken out. This clay rests on the Black Shale. For the manufacture of drain tile, brick, and shingles, the clay is dug, removed to the soak pit, and left over night. The next day the clay is shoveled into the disintegrator, where any stones present in the clay are crushed until the fragments are reduced to a diameter of one sixteenth of an inch or less. From the disintegrator the clay is carried along a belt to the tile mill. Here the clay is pushed out of the tile mill, through the dies, where the proper thickness and width is given to the stream of clay which issues forth. From the tile mill the issuing stream of clay is carried forward by the machine to the cut-off table, where the clay, which already has the proper width and thickness, is cut off into the desired lengths. From the cut-off table the blanks or plates of clay, the future shingles, are carried forward and picked off by boys who haul them to the shingle press.

Up to this point the manufacture of shingle tiles does not

differ in any respect from the manufacture of bricks and drain tiling as carried on at the same factory, except that in each case a different die is used in order to give a different form to the stream of clay issuing from the die, and in each case the wires on the cut-off table are set at different points, so that the length appropriate to the particular object to be manufactured will be cut off. For the manufacture of shingle tiles the clay is heaped up usually about two days, moistened and covered with oil cloth, before it is run through the disintegrator, in order to become evenly moist.

From the cut-off table the clay plates are taken to the press, where they are pressed into shingles. In this machine the upper die is stationary, and there are three lower dies, all of which are movable, only one die being used at a time. One of the clay plates is inserted into the machine and pressed. The lower die with the pressed shingle on it is then lifted up. A pallet or small board slightly larger than the shingle is placed on the shingle. Then die, shingle and pallet together are turned over and the die lifted off, the pressed shingle remaining on the pallet. In the meantime another clay plate has been inserted in the machine and pressed into the shape of a shingle, and is ready to be taken out and placed on a pallet. The shingles, still resting on the pallet, are carried off to the drying shed. The capacity of such a press is 4,000 shingles in one day of ten hours, ten men being employed in various ways.

The shingles are allowed to dry on the pallets for periods varying from two to five days, depending upon the weather. They are then skinned or trimmed. Trimming consists in rubbing off the rough edges of the clay shingles with the back of a coarse knife. Then the shingles are stacked up and taken to the kiln. Here they are set up on edge, eight shingles in each set, with firebricks between the sets. These firebricks are a little higher than the shingles, and so take the weight of the upper tiers of shingles from the tiers stacked up below. The fireclay used is secured on the Adams farm, as is also some of the clay which enters into the clay mixture used for the manufacture of the shingles.

The kiln used is a down-draft kiln. The shingles are heated for twenty-four hours, the fresh steam or water-smoke being let out at the top. No great heat is used during this time, the

object being merely to drive off the water still present in the shingles. Then the heat is raised gradually for forty-eight hours until the shingles become white hot. Then the ovens are closed down, firing ceases, the fire-doors are cemented shut with clay, and for three days the kiln is allowed to cool slowly. It takes a day and a half to empty the kiln, and another day and a half to fill the same again.

Three men can fill the soak pit so as to supply enough clay for fifty squares per day. A square is equivalent to 100 square feet of roof surface, which, in the present instance, requires the use of 260 shingles. Fifty squares therefore would in this case be equivalent to 50x260—13,000 shingles. Two men are needed at the disintegrator. One man is needed at the mill and to take care of the cut-off table. Two men serve as off-barrowers,* who wheel off the clay plates or blanks, to which reference has been made in the preceding lines. One man works the lever at the press, one feeds the press, one dumps the pressed shingle on to the pallet, and one man—the off-barrower—hauls the shingles to the drying room. At the drying room one man is kept busy as a skinner or trimmer. Two off-barrowers are needed to fill the kiln, and one man sets up or stacks the shingles in the kiln. Two men are kept constantly employed in firing the kiln, one serving as the day man, the other as the night man. The men firing the kiln are paid $1.50 per day, and all others are paid $1.00 per day. The man firing the kiln for this wage is given the higher sum of money because he is regarded as an expert. Similar wages are given for similar work at the potteries already mentioned.

The weight of a square of shingles, or of 260 shingles, is about 650 pounds. The exposed surface of the shingles is 9.5 by 6 inches. In the process of burning the clay shrinks five-eighths inch to the foot, and allowance must be made for this in constructing the die. No Seger cones are used in firing the kiln, the temperature being determined approximately by looking at the color of the brick through peep-holes left for this purpose on each side of the door in the front walls of the kiln. Shingles have been made at this factory for about two years. One of the churches at Irvine, in Estill county, is covered with this roofing tile. The shingles seem to be defective, owing to

*Evidently a local substitute for the more generally used term, "off-bearers."—C. J. N.

under-burning, and for this reason the use of Seger cones is recommended. They also have a tendency to open up irregular cracks on burning, and hence tests as to the proper mixtures to be employed should be made, but there is no reason why eventually, with greater experience, the manufacture of roofing tiles should not prove a success.

For purposes of comparison with clays from other localities, the following analyses are given. The clay from Vigo county, Indiana, was used formerly for roofing tile, but cracked in burning. The clay from Prospect Hill, in St. Louis county, Missouri, is used both for brick and for roofing tile. The clay (Chemung shale) from Alfred Center, in Allegheny county, New York, produces an exceptionally good quality of roofing shingle.

	Indiana, Vigo County	Missouri, Prospect Hill	New York, Alfred Center
Silica	73.20	60.70	53.20
Alumina	13.38	18.22	23.25
Ferric oxide	2.19	7.58	10.90
Lime	0.97	2.68	1.01
Magnesia	1.01	Trace	0.62
Soda and potash	.....	3.67	2.70

Since roofing tiles or shingles are to be used in order to shed water, their degree of porosity or permeability to water is of the highest importance. The value of roofing shingles may be tested as follows: Heat the shingle to be tested to a temperature of 212 degrees F., then place on it a tin tube, whose diameter is five inches and whose height is eight inches. This should be fastened to the tile by means of wax applied to the outside of the tube. Fill the tube with water up to a level of four inches above the tile and keep the water at this level by adding a few teaspoonfuls at a time until drops begin to appear on the under side of the tile or shingle. If these drops make their appearance in less than six hours, the roofing tile should be rejected. Tile burned to a higher degree of vitrification is, of course, more impervious to water.

In addition to the roofing tile or shingle, the Lexington Tile

Roof Company manufactures also paving brick, 8¾ inches wide and long, and therefore having a hypothenuse, or diameter from corner to corner, of one foot. The thickness of these bricks is two inches. They are intended for paths in gardens, sidewalks in villages, and the like. They are placed with their greater diameters parallel to the length of the walk, and the gaps thus left at the side of the walk are filled in with half bricks which have a triangular shape, fit in snugly, and are supplied in proper quantities with every order.

In addition to the paving brick, drainage tiling and common brick are manufactured. Several tests of different clays from the Waco area, made by the Boyd Company, of Chicago, at the request of the Lexington Tile Roof Company, have demonstrated that a fine grade of pressed bricks can be manufactured from the different clays. These vary in color from a very light yellow to a distinct red. By a mixture of clays they secured a mottled brick, giving a very pleasing effect. It is evident that the possibilities of these clays have by no means been exhausted. When the dams now under construction along the Kentucky river are completed, the question of cheap transportation from the eastern part of the Waco area should be considered solved.

Directly west of Moberly station is the plant of the Moberly Tiling Manufacturing Company. This is owned chiefly by William Tate. The clay is obtained at the factory. The layer is three feet thick and occurs immediately over black shale. Three or four inches of soil are stripped off at the top. They use the Little Warder press, made at Frankfort, Ind., by the Wallace Manufacturing Company. This turns out 5,000 tiles or 2,000 bricks per day. The cut-off table used is the Euring Automatic Clay Cutter, manufactured by the I. D. Fate Company, at Plymouth, O. The tile truck wagon was made by the Arnold Creager Company, at New London, O. The power for the press and cutter is supplied by a 30 horse-power engine. It requires more power to make the smaller sizes of tiling, four to six inches in diameter, than those of larges size. Labor is paid at the rate of $1.00 per day or ten cents per hour.

The Berea College Brick Company.

The brick yard run by Berea College for its own use and for the employment of some of the college students, is situated about a mile north of town. The clay is obtained from a pit situated northeast of the brick-yard. About three inches of soil are removed, and the underlying clay has a thickness of about three and a half or four feet. It overlies Black Shale. A narrow track with cars is used to haul the clay from the pit to the plant, and then, by means of a cable run by steam, up an incline to the second floor of the building where the bricks are made. At the top of the incline the clay is dumped from the car on to a platform, and then shoveled into the disintegrator. This consists of two large steel rolls, between which the clay passes. Any pebbles present in the clay are ground to small fragments. Water is added to the clay as it reaches these rolls in the disintegrator. From the disintegrator the clay drops into the pug mill. Here revolving blades mix the clay, and if necessary more water is added. In addition to mixing the clay, the blades push the clay forward into the brick mill. This is the Grand Automatic Brick Maker, manufactured by Jonathan Creager's Sons Company, at Cincinnati, O.

The blades in the brick mill push the clay down into the arms of the brick mill, and these arms push the clay sidewise under the press. Here the press pushes the clay into the mold. Nine molds are used when the machine is in operation. Six bricks are made at a time in each mold. In front of the machine one man receives the mold and bumps it to the right and left so as to loosen the clay brick in the mold. Another man picks up the mold and places it on the turn-table, which is a sort of revolving wheel. The open side of the mold is placed against a pallet board and the mold is dumped, leaving the bricks on the pallet board. Then the mold is put in the sander. The sander in use is made by the Wellington Machine Company, at Wellington, O. In the sander the mold is pushed through the sand, and on the other side another man picks up the mold and places it once more in the machine. In the meantime the other molds have been in use. The sand is shipped here from Cincinnati.

Nine pallet boards, with six bricks on each, are loaded on a truck and then are wheeled to the racks. Here they are taken off by a man and are put on the racks to dry. Between six to nine days are necessary for this purpose. The racks at the pallet yard have a capacity of 120,000 bricks. From the pallet yard the bricks are taken to the kiln. Three kilns are in use, one updraft Morrison clamp kiln, and two common updraft kilns. The capacity of these kilns is 225,000, 200,000, and 200,000 bricks. The bricks are first fired for about four or five days to drive off the steam, usually called "water smoke." After this has been driven off, the escape of the heat is cut off, the fires are increased, and in three or four days the bricks come to a red heat, then to a white heat in three and a half or four days additional. After this, all access of air is cut off, and it requires eight days for the kiln to cool.

The capacity of the yard when worked to its fullest extent is 2,000,000 bricks a year. It has been in operation about four years. The machinery for tile-making has been secured. Prof. S. C. Mason, at Berea, the Professor of Agriculture and Geology, is especially interested in this plant. Aside from its usefulness to the college, it is of great service to the students, who here get a practical knowledge of brick-making, which, with modifications, they can directly apply in the mountain districts from which so many come, doing by hand, of course, many of the things which here are done by machinery.

PART III.

MISCELLANEOUS ANALYSES OF KENTUCKY CLAYS AND MARLS.

Taken from the Several Volumes of Published Reports of the Kentucky Geological Survey, and Arranged According to Counties.

Compiled by JAS. H. GARDNER.

MISCELLANEOUS ANALYSES.

PROFESSOR C. J. NORWOOD,

Director, Kentucky Geological Survey.

SIR: I beg to submit herewith a compilation of analyses made of samples of clay and marl gathered from various counties of the State, most of which have been published in the different volumes issued by the State Geological Survey.

Very respectfully,

JAS. H. GARDNER.

BARREN COUNTY.

No. 1665.—Marly deposit in Procter's Cave. In the Cavernous Subcarboniferous limestone, the St. Louis. Said to be good for polishing metals.

Following is the analysis of this material:

Ignition and moisture	5.09
Silica	8.86
Alumina	5.80
Ferric oxide	In alumina
Lime carbonate	66.16
Magnesium carbonate	14.08
Potash	n. e.
Soda	n. e.
	100.99

BOONE COUNTY.

No. 1697—Clay, from three miles west of Burlington. Sent by W. W. Walton.

Presents thin stratified layers of various tints of light brown-

ish-grey and light dove color. Burns hard, and of a handsome light brick color. Melts at a high temperature, hence is not a good fire-clay.

Following is the analysis of sample dried at 212 degrees F.:

Ignition and moisture	8.78
Silica	48.36
Alumina (with iron and manganese oxides and phosphoric acid)	33.06
Lime	3.05
Magnesia	0.36
Potash	4.66
Soda	1.70
	99.97

Boyd County.

No. 1292.—Marly shale. From near the top of the ridge between Clinton Furnace and Cannonsburg.

A friable, indurated marly clay, of dirty-greenish and brownish colors.

Following is the analysis of sample dried at 212 degrees F.:

Ignition and moisture	6.62
Silica	77.56
Alumina and iron and manganese oxides	12.64
Lime carbonate	0.48
Magnesia	0.92
Potash	1.38
Soda	0.08
Phosphoric acid	0.21
Sulphur trioxide	0.07
	99.96

Boyle County.

Light greenish clay from Blue Lick, northwest of Linietta Springs, half a mile northwest of Junction City. Base of the Waverly formation. Collected by Aug. F. Foerste, 1904. Analysis by A. M. Peter.

Composition of air-dried sample:

	Per cent.
Moisture	1.35
Ignition (combined water and volatile matter)	4.85
Silica	62.44
Alumina	17.87
Ferric oxide	6.31
Lime	0.18
Magnesia	1.18
Potash	3.52
Soda	0.77
Titanium dioxide	1.04
Sulphur trioxide	0.19
	99.70

It is possible that this clay may serve for vitrified brick.

Breckenridge County.

No. 312.—Labeled, "Shale and Marl under the Archimedes Limestone, at Ryans, four to four and a half miles east of south of the Breckenridge Coal Mine (Subcarboniferous Limestone formation)." This is from the Chester group. Analysis is of sample dried at 212 degrees F.

A dark olive-grey friable shale, containing ferruginous concretions. Rubbed up in a mortar and washed with water, it left 17 per cent. of very fine sand, of which only 0.20 per cent. would not pass through the bolting cloth. These coarser particles, examined with the aid of the glass, were found to be flattened rounded particles of ferruginous sandstone and rounded particles of hyaline quartz.

No. 2460.—Marly shale. From Buffalo Licks, a mile and a half below Cloverport. Sample sent by Robert Bryce.

This shale contains only a trace of phosphoric acid, and its potash is in such firm combination as not to be immediately available for plant nourishment; so that it does not promise much as a fertilizing agent when applied to the soil. Analysis is of air-dried sample.

No. 1994.—Marly shale. From Tar Creek Hill, Bowling

Green Road, near Cloverport, Breckenridge county. Collected by P. N. Moore. Analysis is of sample dried at 212 degrees F.

A friable shale, of a yellowish olive-grey color, containing many minute specks of mica. Before the blow-pipe it fuses into a dark colored slag. Burns of a handsome bright brick color.

This marly shale would, no doubt, be useful as a fertilizer on old exhausted soils of a light and sandy nature. Exposed to the frosts on the surface of the ground, it would very probably undergo complete disintegration. Its considerable proportion of potash would gradually become available for vegetable nourishment under the influence of the atmospheric agencies, but might perhaps be brought more quickly into use by the simultaneous application of slaked lime on a clover crop. It might be used for terra cotta.

Following are the analyses of these Breckenridge county clays:

	312	2460	1994
Ignition and moisture	7.04	5.44	3.78
Silica	78.68	73.50	66.96
Alumina	12.17	16.76	15.62
Iron oxide	In Al.	In Al.	8.38
Lime	0.97	0.28	0.49
Magnesia	0.41	1.89	0.67
Potash	0.55	2.08	3.29
Soda	0.19	0.03	0.62
Phosphoric acid	0.10	Tr.	0.16
Sulphuric acid	0.19	.....	.....

Clay from land of Mrs. Miller. Sample was a soft, grey, friable material, rather gritty to the touch. It effervesced with acid. Rather easily fusible in the blow-pipe flame. Collected by C. J. Norwood, 1903. Analysis by A. M. Peter.

Analysis of air-dried sample:

	Per cent.
Moisture	0.76
Ignition	5.86
Silica	68.86
Alumina	13.67
Ferric oxide	3.32
Lime	2.90
Magnesia	1.60
Potash	0.47
Soda	0.36
Sulphuric acid	0.14
	97.94

This clay was brought to determine its suitability for making Portland cement. It is too high in silica to be used for such purpose, unless combined with other material much richer in alumina. A test was made as to its possible value as Fuller's earth, but it did not give the color test of that earth. The clay is said to have been used as a polishing powder and as a substitute for soap. It is too gritty for use as polishing powder for fine ware, but may serve for some polishing purposes, and it may prove useful in the manufacture of washing compounds similar to Sapolio.

BUTLER COUNTY.

No. 1996.—Marly clay-shale or indurated clay. Below the coal at the Mud Creek Mines. Collected by John R. Procter.

Of a dark-grey color, imperfectly and irregularly laminated. Contains many minute specks of mica, and some imperfect impressions, apparently of marine shells. It is quite plastic when powdered. Burns of a light yellowish-grey color, nearly white, hence might be made available in terra cotta. Fuses before the blow-pipe.

Following is the analysis of this clay, sample dried at 212 degrees F.:

Ignition and moisture	13.445
Silica	51.660
Alumina	15.560
Ferric oxide	7.680
Lime	7.269
Magnesia	0.817
Potash	3.276
Soda	0.293
	100.000

Clay underlying the coal mined by the Aberdeen Coal and Mining Co., near Morgantown. Thickness, three to five feet. A hard, stony-looking grey clay, with some plant impressions. Collected by H. P. McDonald, 1903. Analysis by A. M. Peter.

Composition of air-dried sample:

	Per cent.
Moisture	1.11
Ignition	4.54
Silica	72.54
Alumina	17.36
Ferric oxide	1.70
Lime	0.35
Magnesia	0.42
Potash	3.26
Soda	.....
Sulphur	0.07
Titanic oxide	0.63
	101.98

The clay contains too large an amount of fluxing material (iron, alkalies, etc.) to be a good fire-clay. The iron and sulphur occur chiefly combined as pyrites. It is possible that considerable of the latter could be removed by washing.

Clay underlying the coal mined by the A. R. Pollock Coal Co., Mining City. Color, light grey, with smooth surfaces and plant impressions. Thickness, three to five feet. Collected by H. P. McDonald, 1903. Analysis by A. M. Peter.

Composition, air-dried:

	Per cent.
Moisture	2.20
Ignition	7.55
Silica	60.61
Alumina	24.18
Ferric oxide	0.95
Lime	0.32
Magnesia	0.88
Potash	3.16
Soda	0.94
Sulphur	0.13
Titanic oxide	0.21
	101.13

The sulphur occurs in the form of pyrites.

CALDWELL COUNTY.

No. 2942.—Marl. Somewhat indurated. From land of Mr. E. M. Stephens, thret miles east of Princeton, Caldwell county, Ky. Bed four feet thick. Mostly in soft, friable laminae, of a light-grey color, nearly white, with some ferruginous stains. Quite plastic with water when pulverized. Fused before the blow-pipe. Did not prove to be "hydraulic" on experiment.

Following is the analysis of air-dried sample of this clay:

Ignition and moisture	20.36
Silica	37.80
Alumina and iron oxides	13.32
Lime carbonate	21.16
Magnesia	1.44
Potash	2.39
Soda	2.23
Phosphoric acid	1.27

CAMPBELL COUNTY.

No. 1315.—Marly shale. Labeled, "Clay marl, from Cincinnati Group; quarter of a mile from Newport on the Alexandria Turnpike; upper blue clay." Collected by N. S. Shaler. Lower Silurian.

A dark-grey, soft shale adhering to the tongue.

No. 1316.—Marl. Labeled "Marl, from the silicious mudstone of Dr. Owen, ten feet from the surface. Not distinctly stratified. Gallows Gap." Collected by N. S. Shaler.

Buff colored; friable; fine grained.

No. 1317.—Clay shale. Labeled "Newport Reservoir; three hundred and forty feet above the Ohio River. A mixture of the clays in a set of beds, containing a few limestone layers, six feet from the surface to twelve feet." Collected by N. S. Shaler.

A yellowish, soft shale, with softer ferruginous clay mixed, adhering to the tongue.

No. 1318.—Clay shale. Labeled, "Newport Reservoir, upper blue clay, three hundred and twenty feet above high water in the Ohio River." Collected by N. S. Shaler.

A dark, bluish-grey soft shale. Adhering to the tongue.

No. 1319.—Clay. Labeled, "Brick Clay, about three feet above high water in the Ohio River; Newport, Ky." Collected by N. S. Shaler.

A light, ferruginous, yellow silicious clay.

No. 1320.—Sandy Ferruginous Clay. Labeled, "Sandy Clay, three feet from surface; Mt. Vernon Road, half a mile from Alexandria Turnpike." Collected by N. S. Shaler.

Of a light reddish-brown color.

No. 1321.—Ferruginous Clay, etc. Labeled, "Ferruginous Conglomerate; side of road, one mile north of Giants Creek. North headwaters of Phillips Creek." Collected by N. S. Shaler.

Ferruginous clay, with nodules of impure hydrated peroxide of iron included.

No. 1322.—Principally sand. Labeled, "Moulding Sand, Columbia Trace, half a mile northeast of Newport Waterworks Reservoir." Collected by N. S. Shaler.

A fine sand of a dirty-salmon color, composed mainly of minute rounded quartz grains.

No. 1323.—Sand. Labeled, "Sand beneath the Brick Clay. Section on Columbia, corner of Harris street, Newport, Ky." Collected by N. S. Shaler.

No. 1335.—Marly Shale. From two miles south of Newport, Licking Three Mile creek. Geological position: "Cincinnati Group, fifty feet above high water mark of the Ohio river." Collected by N. S. Shaler.

A friable shale of a handsome light olive-grey color, containing fragments of small encrinital stems and of *Orthis multicosta.*

No. 1336.—Marly Shale, "from Licking Three Mile Creek, two miles back of Newport (Cincinnati group). About sixty feet above high water mark in the Ohio River. The beds are about thirty feet thick, with thin partings, and can be easily stripped. Test their value as a marl." Collected by N. S. Shaler.

Of a light olive-grey color. The laminae are thinner than the preceding.

Following is a table of these Campbell county clays, dried at 212 degrees F.:

County	No.	Ignition and Moisture	Silica	Albumina	Ferric Oxide	Lime carbonate	Magnesia carbonate	Potash	Soda	Phosphoric Acid	Sulphuric Acid
Campbell	1315	5.76	47.32	28.05	In Al.	13.49	1.13	3.25	0.64	0.34	n. e.
Campbell	1316	2.94	68.76	12.05	In Al.	9.86	3.86	1.33	0.98	0.22	n. e.
Campbell	1317	4.70	58.08	31.49	In Al.	0.66	1.13	3.04	0.99	0.25	.....
Campbell	1318	6.20	51.42	29.45	In Al.	6.85	1.26	4.12	0.57	0.12	.....
Campbell	1319	4.57	72.66	20.50	In Al.	Tr.	0.83	1.24	n. e.	0.19	.....
Campbell	1320	4.10	82.56	12.22	In Al.	0.16	Tr.	0.67	0.28	n. e.	.....
Campbell	1321	3.41	57.16	33.54	In Al.	0.86	1.78	2.70	0.55	n. e.	.....
Campbell	1322	4.40	81.66	12.70	In Al.	Tr.	Tr.	0.76	0.64	n. e.	.....
Campbell	1323	2.96	85.84	3.50	In Al.	7.40	0.30	n. e.	n. e.	n. e.	.....
Campbell	1335	4.89	54.16	12.26	15.55	7.80	0.16	3.30	0.93	0.28	0.66
Campbell	1336	3.34	57.26	16.78	11.50	4.56	0.78	4.47	1.07	Tr.	0.23

CARTER COUNTY.

No. 2461.—Marl. "From mines of Carter County Limestone Mfg. Co. Found in their quarry, in a bed about three feet thick. Supposed to be useful as a fertilizer."

A compact marl, of chocolate and dirty green color. Ad-

heres to the tongue. Soft enough to be scratched by the nail.

As this contains a considerable percentage of carbonate of lime and magnesia, as well as a fair proportion of phosphoric acid and 3 per cent. of potash, which, however, would not be immediately available as a fertilizer, this marl may be found beneficial on poor, sandy soil in its immediate vicinity, where the cost of transportaton would not preclude its use.

The sample of this marl was accompanied by two lumps of nearly white limestone from the quarry in which the marl bed is found. This limestone is a compact, light cream-colored rock, containing specks of small crystals of calc spar. On testing, it was found to be nearly pure carbonate of lime, containing only a trace of phosphoric acid. The proprietors were said to have crushed this limestone for use as a fertilizer. Its principal valuable ingredient is its carbonate of lime; it is therefore not better as a fertilizer than any ordinary limestone.

Analysis of the air-dried sample of the marl is as follows:

	Per cent.
Water and loss	2.37
Silica	58.44
Alumina	13.37
Ferric oxide	5.00
Lime carbonate	13.88
Magnesia carbonate	3.42
Potash	3.02
Soda	0.28
Phosphoric acid	0.20
	99.98

No. 1337.—Clay. Labeled, "Fire Clay; average sample from the upper bed, four feet thick on both sides of the hill. Ridge between Grassy and Three Prong Creeks, Boone Furnace property. Whole bed eight to ten feet thick. Collected by Philip N. Moore.

The dried clay is quite compact, scarcely to be scratched with the nail; has a soapy feel; not adhering to the tongue. Breaks into sharp angular fragments. It is of a light-grey color.

No. 1338.—Clay. "From ridge between Grassy and Three Prong Creeks, Boone Furnace propery. Lower bed. Collected by P. N. Moore.

Compact, breaking into sharp angular fragments; hardly to be scratched with the nail; slightly adhering to the tongue; has a somewhat soapy feel. Presents, in parts, an approach to an oolitic structure. Color, dark-grey, passing into dove color.

No. 1339.—Clay. "From same locality as preceding. Rougher part of the upper layer, etc. Collected by P. N. Moore."

A light-grey compact rock, of a harsh gritty feel; not to be scratched with the nail. Under the glass showing many rounded grains of quartzose sand. Ferruginous incrustation on the surface.

No. 1340.—Clay. "Fire Clay under coal. Old Orchard Diggings, Boone Furnace Property, Carter county. Collected by P. N. Moore.

A compact shaly clay, with some of the lamellar surfaces polished in various planes. Has a soapy feel, and no grit. Of a dull dove-grey color.

No. 1341.—Clay. "Fire-clay from same bed as Nos. 1337, 1338, and 1339. A dark-colored sample from the lower part of the deposit." Collected by P. N. Moore.

Compact, fine-grained; hardly scratched with the nail; adhering very slightly to the tongue. Of a dark brownish- slate color.

No. 1342.—Clay. "Fire Clay under the twelve-inch coal. Geo. Oseton's Land, near Grayson, Carter county. Sampled by J. A. Monroe."

A grey or ash-grey clay in pulverulent condition.

No. 1343.—Clay Shale. Labeled, "Argillaceous Shale, with some lingulae near the top. Railroad cut, half mile south of Station (Eastern Ky. Railroad), Grayson, Carter county. Collected by Prof. N. S. Shaler."

A soft, friable shale, of a bright buff-grey color, mottled and colored between the laminae with ferruginous and black.

No. 2289.—Ferruginous Marly Clay. "From Limestone Mining Co., Limestone Station, Carter county. Sample sent by John R. Procter. Received Aug. 23, 1883."

In lumps, easily broken, of a chocolate-brown color, containing small rounded grains of hyaline quartz, and small pebbles,

more or less rounded, of various quartzose minerals. By washing, about one-fourth its weight of small rounded quartzose pebbles and fine sand was separated. The residue is a tough, plastic clay, of a light chocolate color, fusing before the blow-pipe into a dark-colored, nearly black slag.

Analysis of this clay (exclusive of pebbles and sand), dried at 230 to 240 degrees F., is as follows:

	Per cent.
Moisture and loss	2.950
Silica	62.680
Alumina	14.803
Ferric oxide	6.160
Lime carbonate	8.280
Magnesia carbonate	1.650
Potash	3.108
Soda	2.149
Phosphoric acid	0.217
	100.000

The analysis was made by the late Robt. Peter, M. D., then Chemist of the Survey. His comments are: "This clay might be of some service as a marl on poor sandy soil, provided the cost of transportation does not preclude its use. The washed clay might be employed in the manufacture of common pottery of various kinds." It will be observed that the percentages of iron and alkalies are high, hence the clay would seem more serviceable for brick than pottery.

No. 2463.—Fire Clay (Sample No. 1). "From Perry's branch of Tygart's creek, near its mouth, and near the E. L. & B. S. R. R. Thickness of bed, three to nine feet. Owned by the Tygart Valley Iron Company. Sample sent by K. B. Grahn, Secretary and Treasurer of the company, Olive Hill, Carter county."

A very light grey, nearly white, compact, indurated clay. Breaks easily, with irregular, broad conchoidal fracture. Adheres slightly to the tongue. Imperfectly oolitic, with small spheroidal concretions of the size of a mustard seed. Before the blow-pipe it calcines white and is quite refractory, softening very little in the greatest heat.

No. 2464.—Fire Clay (Sample No. 2). From the same locality as the preceding, etc.

A compact, indurated clay, of a yellowish light-grey tint; more firm than the preceding clay. Does not adhere to the tongue. Is a little more oolitic than that. The exterior surfaces are strongly colored with iron peroxide. Before the blow-pipe it calcines nearly white, with a slight tint of reddish. Is refractory, but softens a little in the intense heat.

No. 2465.—Fire Clay (Sample No. 3). "From the same locality as the preceding, etc.

Resembles the next preceding in firmness, fracture and oolitic character. Does not adhere to the tongue. Calcines, before the blow-pipe, of a light brick-reddish color. Is refractory, but softens a little more than the preceding in the intense heat.

No. 2466.—Fire Clay (Sample No. 4). "From same locality as the preceding, etc."

Resembles the preceding, but is rather more oolitic. Is of a brown-grey color, with a thin, irregular vein of greenish-grey. Hardly adheres to the tongue. Before the blow-pipe it calcines of a light brick-reddish tint. Is refractory, but softens a little more than the preceding. For comparison, the analysis of the celebrated "Woodbridge's Fire Clay," of New Jersey, is given, numbered as 2467.

No. 2467.—Woodbridge Fire Clay, from New Jersey. The analysis is taken from the second report of the Geological Survey of New Jersey, 1855, page 100. This Woodbridge fire-clay is said (in the New Jersey report) to be of the "best fire-clay," and that it will "stand an intense heat better than the imported brick." The best sample of the Carter county clay, No. 2463, contains less of the ordinary fluxing materials of clays, viz., iron oxide, lime, magnesia, potash and soda, and the other samples exceed it only in iron oxide, much of which—it being mainly an exterior coating—could probably be excluded in mining or removed by scraping.

No. 2661 N. S.—Fire Clay. Labeled "Ashland Fire Brick Company. Green No. 1." A hard gray, flint clay. No effervescence with hydrochloric acid. No phosphoric acid. Part of sample reserved. Analyzed by S. D. Averitt, 1905.

No. 2662 N. S.—Fire Clay. Labeled "U. S. Tabor, No. 1." A hard, gray flint clay. No effervescence with hydrochloric acid. No test for phosphoric acid. Collected by W. U. Grider. Analyzed by S. D. Averitt, 1905.

No. 2663 N. S.—Fire Clay. Labeled "One mile north of Olive Hill. This clay underlies six inches of black shale, above which comes the Conglomerate Sandstone." Collected by W. U. Grider. Analyzed by S. D. Averitt, 1905.

A semi-hard clay of a dark, gray color and soapy feel. No effervescence with hydrochloric acid and gave no test for phosphoric acid.

The following tables show the analyses of the Carter county clays that have been described:

No.	Dried at	Moisture and Ignition	Silica	Alumina	Ferric Oxide	Lime	Magnesia	Potash	Soda	Phosphoric Acid
1337	212° F.	13.03	48.56	37.47	tr.	0.11	tr.	0.28	0.28	tr.
1338	212° F.	14.21	45.96	38.53	tr.	0.14	tr.	0.25	0.34	tr.
1339	212° F.	11.78	54.62	32.46	tr.	tr.	tr.	0.21	0.67	tr.
1340	212° F.	7.75	62.46	27.20	tr.	tr.	tr.	1.85	0.58	tr.
1341	212° F.	8.52	45.56	43.77	tr.	0.14	tr.	0.96	0.72	tr.
1342	212° F.	8.30	64.26	24.60	tr.	0.53	0.20	0.75	0.51	0.15
1343	212° F.	5.30	66.06	23.72	tr.	.....	0.12	2.09	2.27	n. e.
2463	Air	14.43	43.58	40.86	0.76	0.29	0.14	0.19	0.05	.....
2464	Air	12.65	44.84	40.18	1.76	0.21	0.13	0.17	0.06	.....
2465	Air	12.86	41.28	40.56	4.42	0.60	0.17	0.11	tr.	.....
2466	Air	15.69	41.58	38.38	4.04	0.21	0.10	tr.	tr.	.....

No. 2467.—Analysis of the Woodbridge, N. J., clay. Composition, air-dried:

	Per cent.
Water and loss	14.640
Silica	39.760
Alumina	42.850
Iron peroxide	0.940
Lime	0.398
Magnesia	0.650
Potash	0.477
Soda	.....
	99.715

Analyses of other Carter county clays, being Nos. 2661, 2662 and 2663 of the new series. Analyses made by S. D. Averitt, 1905. Composition, air-dried:

	No. 2661	No. 2662	No. 2663
Moisture	0.88	0.58	1.17
Ignition (combined water and volatile matter)	13.24	13.64	13.21
Silica	45.56	43.90	43.76
Alumina	35.75	36.82	36.47
Ferric oxide	0.87	0.72	1.02
Lime	0.28	0.33	0.34
Magnesia	0.40	0.27	0.29
Potash	0.59	0.25	0.31
Soda	0.39	0.16	0.19
Titanium dioxide	1.80	3.10	3.05
Sulphur trioxide	0.40	0.15	0.07

Clark County.

No. 2671 N. S.—Red Devonian Clay, from Orlando Hensley's place, three miles east of Indian Fields. Thickness, fifty-four inches. Collected by J. H. Gardner, 1905. Analysis by A. M. Peter.

Composition, air-dried:

	Per cent.
Moisture	3.04
Ignition (combined water and volatile matter)	12.28
Silica	44.40
Alumina	11.35
Ferric oxide	24.69
Lime	0.26
Magnesia	0.38
Potash	1.99
Soda	0.26
Titanic oxide	0.75
Sulphur trioxide	0.56
Phosphorus pentoxide	0.13
	100.09

CLINTON COUNTY.

No. 1741.—"Marly Clay, Cumberland City Mines, Chester Group (Leitchfield Marls). Collected by Prof. N. S. Shaler."

A dull, olive-grey, indurated marly clay. Following is the analysis:

Silica	70.80
Alumina and iron oxides	18.84
Lime	0.59
Magnesia	4.35
Potash	4.24
Soda	0.79

CRITTENDEN COUNTY.

No. 12950.—Soft, powdery, nearly white clay, from farm of C. W. Bryant, three miles southwest of Marion. Collected by L. P. Tanner, in accordance with directions of Prof. C. J. Norwood, 1903. A sample pitcher was made of this clay by the Brockman Pottery Company, Cincinnati, O. The glazed ware is white, with a faintly bluish tinge. Analysis by A. M. Peter.

Composition, air-dried:

	Per cent.
Moisture	1.36
Ignition	9.78
Silica	57.56
Alumina	30.47
Ferric oxide	trace
Lime	0.30
Magnesia	0.24
Potash	0.26
Soda	0.20
Sulphuric anhydride	trace
	100.17

EDMONSON COUNTY.

No. 1767.—Silicious Clay, from Sowder's farm, near Green River. Chester Group. Bed four to six feet thick. Collected by John P. Procter. In irregular lumps; friable; of an olive and brownish-grey color. Powder light-grey.

No. 1768.—"Clay, from Sowder's farm, on Caney Branch, one mile from Green River. Bed seven to eight feet thick, in layers of various colors. Collected by John R. Procter."

(*a*) The upper or light-dove-colored layer.

(*b*) The second, light-grey, nearly white layer.

(*c*) The third, grey layer.

(*d*) The lowest layer. Olive-grey, mottled with yellowish-grey.

Composition of these Edmonson County clays:

Edmonson County	No. 1767	No. 1768 (a)	No. 1768 (b)	No. 1768 (c)	No. 1768 (d)
Ignition and moisture...	2.48	4.34	4.46	4.90	5.69
Silica	80.16	77.66	74.46	71.56	67.56
Alumina and iron oxides	11.60	16.80	20.44	22.86	22.54
Lime	0.76	0.48	0.64	0.68	0.98
Magnesia	0.56	N. E.	N. E.	N. E.	0.67
Potash	3.85	1.00	N. E.	N. E.	2.47
Soda	0.58	0.48	N. E.	N. E.	0.05
Phosphoric acid	.....	.....	.....	.....	Tr.
Sulphuric acid.....	.....	.....	Tr.	.....	.....

For other Edmonson county clays, see Part I. of this bulletin.

Fayette County.

No. 2120.—"Marly Clay, occurring in a bed described as being a foot and a half thick, in the Lower Silurian limestone strata on Elk Lick, between the Kentucky River and the Lexington and Richmond Turnpike, just above the so-called petrified falls (calcareous tufa) of Elk Lick. Collected by Waldemar Mentelle."

A whitish clay, mottled with brownish ochreous spots. Quite plastic. Effervesces with hydrochloric acid. At a moderate red heat it calcines (or "burns") of a handsome flesh color, which property might commend it for use for terra cotta, if in sufficient abundance. Before the blow-pipe it readily fuses into a whitish slag.

No. 971.—Marly Clay. From "Daniel Brink's place; one hundred and two feet above Philip Brink's branch. (Brought by Messrs. Downie and Lesquereux.)"

A light-grey clay, mottled with buff. Contains an extraordinary quantity of potash, etc., and hence might profitably be used as a marl, on land which has been deteriorated by long cultivation.

Composition of these Fayette county marls, dried at 212 degrees F.:

	No. 2120	No. 971
Ignition and moisture	7.87	5.67
Silica	53.78	56.88
Alumina	23.26	24.65
Iron oxides	1.30	.....
Lime	4.86	2.48
Magnesia	0.56	3.27
Potash	7.61	6.65
Soda	0.55	0.19
Phosphoric acid	0.19	0.18

Fleming County.

No. 972.—Marl. Labeled, "Clay found at the junction of the Upper and Lower Silurian of Fleming County."

A greenish and reddish brown clay. Before the blow-pipe, melting at the edges, and burning of light umber color. Powder light dirty-buff. Dried at 212 degrees, it lost 1.20 per cent. moisture.

May be employed as a marl on land, with the addition of bone dust, or super-phosphate, or other phosphatic material.

The following is the composition of this marl:

Ignition and moisture	13.90
Silica	39.78
Alumina	10.40
Ferric oxide	10.76
Lime	16.88
Magnesia	6.38
Potash	1.14
Manganese dioxide	1.08
Phosphoric acid	0.07
Sulphuric acid	0.33

FRANKLIN COUNTY.

No. 1431.—"Green Marly Shale from below the arsenal at Frankfort. Bed about eight inches thick. Ordovician."

A friable shale of a greyish-green color.

No. 1432.—"Marly Shale. Same locality as the preceding, but lying above that. Collected by N. S. Shaler."

Quite friable. Of dull olive and brownish colors.

No. 1433.—"Marly Shale. Used as a paint at Frankfort, etc. Sent for analysis by James L. Sneed."

Of an olive grey color, with some brownish yellow mixed.

No. 1434.—"Marly Shale. From Armstrong's Farm, Bridgeport. Geological position: Cincinnati Group, just below the silicious mudstone. In same position as the marl near Newport. Collected by Prof. N. S. Shaler." Used for paint. Said to be good for polishing iron, etc. Of a handsome light olive-grey color.

These marly shales are remarkable for their large percentage of potash, which probably may make them valuable for application to exhausted land of a light and sandy nature. A previous moderate calcination with lime intimately mixed might, if practicable, make them more available in this respect by setting free more or less of the potash locked up in the insoluble silicates.

It will be seen that No. 1431 contains in all as much as 8.47 per cent. potash, and No. 1432 a total amount of 7.13 per cent.

These and similar marly shales have been used as pigments; for which purpose they are quite appropriate, if of an agreeable tint, and they will not decompose the oil with which they are mixed, and not readily altered by atmospheric agencies under such conditions, and contain nothing of a poisonous nature. Their use for scouring or polishing depends on the very fine silicious sand contained in them.

Although the sulphur and iron in these marls are calculated in these analyses as sulphuric acid and iron oxide, severally, a portion of each, not determined, is combined as iron sulphide.

These latter two analyses were made by employing complete decomposition by fusion, while the first two were analyzed by digestion of the marls in acids, and the subsequent fusion of

the insoluble silicates for the determination of the total amount of the alkalies. The remarks appended to the first two apply equally to these.

No. 2007.—Potter's Clay. From a bed several feet in thickness, in the bottom land in what is supposed to be an old channel of Kentucky River, half a mile north of Frankfort. Collected by John R. Procter.

The clay is of a grey-drab or neutral tint; it contains some very small specks of mica and of ferruginous matter. It calcines of a very light brick color. Fuses before the blow-pipe. Ten grammes of the clay, dried at the common temperature, washed quickly with water, gave 2.45 grammes of fine sand, containing some larger, rounded quartz grains.

This clay, while fitted for the manufacture of ordinary pottery ware, is not sufficiently refractory to be used as a fire-clay.

Composition of the Franklin county clays:

	No. 1431	No. 1432	No. 1433	No. 1434	No. 2007
Ignition and moisture	5.35	6.40	8.34	7.67	5.43
Silica	77.38	70.06	50.36	52.06	69.30
Alumina	10.41	15.39	16.81	18.83	21.78
Ferric oxide	In Al.	In Al.	6.99	9.20	In Al.
Lime	1.44	0.87	8.73	3.66	0.15
Magnesia	0.80	2.29	0.93	1.21	0.33
Potash	3.48	3.56	3.62	5.40	2.35
Soda	0.04	0.31	1.73	0.72	0.58
Sulphuric acid	0.73	0.57	2.28	0.92	.....
Phosphoric acid	.....	.....	.....	.....	0.06

Grant County.

No. 990.—Marl. Labeled, "Marl, alternating with Blue Limestone; in the Milk-sick region, at Moses Theobalds, Grant county."

A greenish-grey, friable marly clay. The air-dried marl lost 1 per cent. of moisture at 212 degrees F. Containing considerable proportions of potash, carbonate of lime, magnesia, and sulphuric and phosphoric acids, it would be a useful top-dressing to exhausted land.

No. 991.—Shale. Labeled, "Shale from the Milk-sick region, Moses Theobalds, Grant county."

A greenish-grey and buff-grey, soft shale, or indurated clay. Dried at 212 degrees F., it lost 1.40 per cent. moisture.

Contains also a considerable quantity of potash.

Following are the analyses of these samples:

	No. 990	No. 991
Ignition and moisture	1.53	3.07
Silica	71.28	78.48
Alumina and iron oxides	16.25	13.34
Lime	4.98	2.78
Magnesia	3.28	1.40
Potash	0.98	0.95
Soda	0.17	Tr.
Phosphoric acid	0.31	0.33
Sulphuric acid	1.19	0.63

Grayson County.

No. 1788.—"Ferruginous Clay. Nodular. Below the upper limestone. Hat branch of Bear creek. Three and a half to four feet thick."

Of a handsome chocolate-brown color. Not adhering much to the tongue. Powder of a handsome grey-chocolate color.

No. 1789.—"Nodular Ferruginous Clay. Canalaway creek." Resembles the preceding.

No. 1790.—Marly Shale. Found below the limestone. Hat branch of Bear creek. Four feet thick. Collected by John R. Procter.

Breaking easily when dry. Of a greyish-olive-green color, with some parts brownish. Not adhering much to the tongue. Powder of a handsome greenish-grey color.

No. 1791.—"Marly Shale. Haycraft's Lick. Similar to preceding."

Of a dark olive-grey color when dry.

No. 1792.—Red marly shale, same locality as preceding, etc. Mixed with the foregoing. Of a chocolate-brown color.

No. 1793.—"Brown Marly Clay. Cedar Knob Lick."

Of a dark reddish-brown or chocolate color when dry. Conglomeratic, with fragments of material similar to No. 1792.

The apparent excess in the total of analysis 1788 and analysis 1789 is due to the alkalies in the insoluble silicates, which are estimated also in the total alkalies given above.

The percentage of alumina in analysis 1789 includes prosphoric acid and manganese oxide, not separately estimated.

These ferruginous and marly shales and clays, when of a good color, may be termed mineral paints, and be very profitably used in that way; but, in consequence of their large proportions of alkalies, especially of potash, as well as of phosphoric acid, they promise to be quite valuable, applied as top dressing, for renewing old worn-out tobacco soil. As they are found in enormous quantities over a great extent of country, the best method of making them profitably available is a matter of great interest.

Chemical analyses show that, while a portion of their alkaline constituents is soluble in acids, the larger part of them is locked up in the insoluble silicates. Spread upon the soil, therefore, without admixture or preparation, their ameliorating influence would probably result more from their large proportion of the elements of clay, giving the soil more consistence, and increasing its power of absorbing atmospheric agencies, etc., than from the alkalies or phosphoric acid, etc., they contain. In short, the application of these marls to the surface might be like the plowing up of a subsoil, rich in the mineral elements of plant food, but poor in the organic compounds which help to bring them into a soluble and available state.

Exposed to the atmospheric agencies, however, the insoluble silicates undergo a gradual, slow decomposition, and their valuable ingredients are thus set free for the use of plants. The decomposing remains of vegetables accelerate this process, and hence the great propriety of using these marls together with stable manures or other organic fertilizers, or of employing a clover or other green crop, plowed in, as a means of disintegrating the silicates. Doubtless poor, exhausted land, which had been top-dressed with the marl, and then sowed in clover, which after the growth of one or two seasons, was plowed in, would

be found to be greatly improved in fertility. A similar result, in some degree, might possibly be obtained, in a single season, by the use of buckwheat, plowed in at maturity.

A quicker mode of setting free the alkalies, etc., of these marls would necessarily be more expensive. The process used in the chemical analysis, namely, that of heating to a moderate red heat, the mixture of the finely-ground marl with a large proportion of pulverized lime, and about an equal proportion of sal-ammoniac (ammonium chloride), is quite effectual in separating all the alkalies of the insoluble silicates. But it is somewhat expensive on a large scale. In this process, the mutual reaction of the carbonate of lime and sal-ammoniac produces carbonate of ammonia, which evaporates and is lost, and calcium chloride, which, together with the excess of carbonate of lime present (calcined in the process partly into caustic lime), cause the decomposition of the silicates, and set free the alkalies. Calcium chloride and carbonate of lime, then, are the essential decomposing agents in this process; and as calcium chloride is present in the bittern water of all salt works, and frequently thrown away as a waste product in other manufactories, or may be cheaply made by the application of hydrochloric acid to limestone, this process would be much more economical than that of the use of the ammonia salt.*

For the decomposition of the marl, not only must it be brought into the plastic state or be powdered, but the limestone or lime, with which it is to be mixed, must also be in the form of powder, so that they may be intimately mixed together and fully incorporated with the calcium chloride. With a cheap powder and a good mill this might not be very expensive. In order to calcine the mixture, the plastic mass, produced by working up together the marl, lime and solution of calcium chloride, should be made up into lumps or brick-like masses, dried to a certain extent, and then calcined at a moderate red heat, not sufficient to fuse them. The time during which they should be maintained at a red heat need not exceed a few hours.

Other modes might be available; as by the use of chlorine gas, which, if the lumps of the marl are porous, would not necessitate pulverization. This gas is to be cheaply obtained from

*Remarks on the proposition to use the bittern water of salt works will be found in Vol. A, part 1, page 231, Kentucky Geological Survey Reports.—J. H. G.

the low-priced hydrochloric acid and oxide of manganese mixed, and if it be allowed to pass slowly from above through the marl lumps contained in a tall, tight cylindrical receptacle, would exert considerable decomposing influence upon the silicates. This process would doubtless be as expensive as the above named.

The mere mixture of slaked lime with the powdered marl, when applied to the land, would doubtless be beneficial in accelerating its decomposition, and calcining them together at a moderate red heat might be yet more useful, especially if a little common salt be added. Indeed, merely calcining the clay alone, if the heat is not sufficient to fuse it, seems to set some of its alkaline constituents free; and hence, probably one reason of the improvement of soil by the old English method of paring and burning it.

No. 1446.—Marly Shale. "From Sunset Lick, a mile and a half west of Leitchfield. Geological position: Chester. Collected by Prof. N. S. Shaler."

A friable marly shale of a greyish and brownish-olive color. This marl when analyzed by digestion in acids, etc., and dried at 212 degrees F., gave the analysis as shown in the table.

The silica and insoluble silicates of this clay, when sintered with lime carbonate and ammonium chloride, etc., yielded 1.20 per cent. of potash and 0.55 per cent. of soda, in addition to that given above as extracted by digestion in acids. So that the total amount of potash in the marl appears to be 4.11 per cent. and that of soda 0.60 per cent.

Some of the same marl shale from this locality subsequently collected by Mr. P. N. Moore, was analyzed by fusion with the mixed alkaline carbonates; sintering with lime carbonate and ammonium chloride, etc., and gave the results as shown in analysis No. 1446 (b).

The apparent excess in the total may be partly due to oxidation of combined iron and sulphur in the marl, and probably, also, to an over-estimation of the water.

Its considerable proportion of potash might make it useful as a fertilizer on impoverished land, were it all in an available condition. But the analyses show that a great portion of it is in firm combination in the silicates, insoluble in acids. Whether lime could profitably be used to decompose these silicates and set free the alkalies is yet to be tried.

Composition of the Grayson county marls, etc.:

Nos.	1788	1789	1790	1791	1792	1793	1746	1746-b
Ignition and moisture..	7.00	8.25	6.13	4.24	3.67	9.87	6.23	6.00
Silica	74.36	68.38	44.76	59.92	58.96	60.76	71.58	60.06
Alumina	14.45	12.28	26.22	27.81	25.75	23.07	19.13	14.13
Ferric oxides.....	In Al.	7.58	In Al.	In Al.	In Al.	In Al.	In Al.	13.48
Lime	1.16	1.38	9.16	0.88	1.58	1.18	0.26	0.53
Magnesia	1.71	1.64	6.62	0.82	4.43	0.49	0.35	1.15
Potash	4.24	5.04	4.94	5.55	5.14	4.09	2.91	4.62
Soda	0.94	1.06	1.06	0.65	0.34	0.43	0.05	0.78
Phosphoric acid	1.08	.....	.....	.....	.....	.....	0.26	0.20
Sulphuric acid.....	.....	.....	1.08	0.10	0.10	0.08	0.02	0.28

GREENUP COUNTY.

No. 2664.—Flint Fire-clay. Is the "No. 1" clay of the Tygart Fire Brick Co., Fullerton. Thickness, sixty to eighty-four inches. Collected by W. U. Grider, 1903. Analysis of air-dried sample by S. D. Averitt.

No. 2665.—The "No. 2" fire-clay of the Tygart Fire Brick Co., Fullerton. A gray, shaly clay. Collected by W. U. Grider, 1903. Analysis of air-dried sample by S. D. Averitt.

	No. 2664	No. 2665
Moisture	0.51	0.68
Ignition	14.13	6.58
Silica	42.52	67.54
Alumina	35.81	19.93
Ferric oxide	3.24	1.26
Lime	0.34	0.29
Magnesia	0.12	0.14
Potash	0.20	1.41
Soda	0.20	0.22
Titanium dioxide	2.00	1.60
Sulphur trioxide	0.09	0.12
	99.16	99.77

HART COUNTY.

For analyses of Hart county clays see Part I. of this Bulletin.

HENDERSON COUNTY.

Clay from under the coal mined by the Utopia Coal Co., on Green river. Collected in 1903 by H. P. McDonald. Thickness, four to five feet. A gray clay with smooth, polished surfaces and plant impressions. Analysis of air-dried sample by Dr. A. M. Peter:

	Per cent.
Moisture	5.49
Combined water, etc.	5.86
Silica	56.78
Alumina	23.48
Ferric oxide	2.82
Lime	0.47
Magnesia	1.26
Potash	3.36
Soda	1.04
Sulphur	0.58
Titanic oxide	0.60
	101.74

The clay contains too much iron and alkalies to be useful for refractory purposes.

JEFFERSON COUNTY.

No. 2165.—"Shaly Clay (or clay shale) in the limestone layers of the 'Cincinnati Group.' Lower Silurian. Jeffersontown." Collected by Rev. H. Hertzer.

A friable shale, generally of a lilac-grey color, but with some whitish portions. When powdered, it is quite plastic with water. It calcines of a light brick color, but before the blow-pipe it fuses into a dark-colored slag.

No. 2166.—"Shaly Clay, of the Keokuk Group, from Cox's Knob, Jefferson county." Collected by Rev. H. Hertzer.

Generally of an olive-grey color. This also is quite plastic when powdered. It calcines of a very light brick color. Before the blow-pipe it fuses into a dark-colored slag.

No. 2167.—"Shaly Clay (or clay shale) of the Keokuk Group. From the old Deposit Station, Jefferson county." Collected by Rev. H. Hertzer.

A friable shale or indurated clay of a light buff-grey color, with ferruginous stains between some of the laminae. Quite plastic when powdered. It burns of a light brick color, and fuses before the blow-pipe into a dark-colored slag.

No. 1069.—Marl. Labeled "Marl from Chenowick creek, Jefferson county, Ky."

A greenish-grey, clay-like substance, with some thin brownish infiltrations. Dried at 212 degrees F., it lost 0.90 per cent. of moisture.

This would prove a valuable application to exhausted land.

Following are the analyses of these Jefferson county clays:

	No. 21.5	No. 2166	No. 2167	No. 1069
Ignition and moisture	9.23	5.96	6.49	2.19
Silica	47.96	58.84	61.90	59.90
Alumina	21.34	19.94	18.52	7.26
Iron oxides	6.60	6.00	6.22	In Al.
Lime	5.82	3.22	0.12	*a*26.88
Magnesia	3.52	0.85	1.25	1.68
Potash	5.26	4.49	4.86	0.96
Soda	0.25	0.68	0.61	0.01
Phosphoric acid	Tr.	Tr.	Tr.	0.69
Sulphuric acid	.....	.....	Tr.	0.40

a. Lime carbonate.

KENTON COUNTY.

No. 1581.—"Silicious Grit at first tollgate, two miles from Covington, on Lexington Turnpike. Collected by Prof. N. S. Shaler."

A brownish-grey, ferruginous impure sandy mass.

No. 1582.—"Silicious Grit from same locality as preceding. Used for 'moulding sand.' Collected by Prof. N. S. Shaler."

An impure, reddish-brown friable sandy mass; infiltrated

with iron oxide; varying in tint from grey to deep brown. The sand grains are rounded.

The amount of alkalies contained in these impure sands is somewhat remarkable. They exist in them, however, mostly in the insoluble silicates, and were separated in the analyses by the process of fusion with the mixture of lime carbonate and ammonium chloride, etc., according to the method of J. Lawrence Smith. Notwithstanding the unavailable condition of these alkalies, these sands might prove useful additions to heavy clay soils, more especially because of their notable proportion of phosphoric acid. For this purpose, however, they could only be employed in the close vicinity of their beds, as they would not pay for long transportation.

No. 1583.—"Clay, supposed to be in the Cincinnati Group of the Lower Silurian formation. Lexington Turnpike, two miles south of Covington. Top section just below that of the preceding grits. Collected by Prof. N. S. Shaler."

A laminated or shaly clay of handsome light-buff and bluish-grey, alternating.

No. 1584.—Clay. "Clay-pit at brick-yard. Head of Russell street, Covington. Average of the nine-feet section. Collected by Prof. N. S. Shaler."

A yellowish ferruginous clay; mottled with light bluish-grey; containing fine silicious grains.

No. 1585.—Marly Shale. "Junction of the Ohio and Licking rivers, twelve feet above low water mark. Cincinnati Group. Collected by Prof. N. S. Shaler.

A fine-grained, dark-grey shale; dull; adhering somewhat to the tongue.

No. 1586.—Marly Shale. Labeled, "Fine shales, between impure limestone; five feet above low water mark. Whitehall. No fossils. Collected by N. S. Shaler."

A soft friable shale; dark-grey in the fresh fracture; adhering to the tongue.

These marly shales would undoubtedly be valuable for top dressing poor light soils in their vicinity, notwithstanding most of their alkaline ingredients are in a state of combination which renders them, for the present, unavailable for plant nourish-

ment. The gradual action of atmospheric agencies and of humus, as well as that of the lime, will eventually bring them into a soluble state. The latter two may be considered the best for this purpose.

Following are the analyses of these Kenton county clays:

	No. 1581	No. 1582	No. 1583	No. 1584	No. 1585	No. 1586
Ignition and moisture....	4.50	5.10	7.10	3.65	3.85	5.20
Silica	77.46	75.70	56.40	68.36	43.46	47.16
Alumina and iron oxides.	16.50	15.79	29.97	22.25	21.00	22.85
Lime	0.48	0.66	0.76	1.00	27.04	20.14
Magnesia	0.12	0.21	1.51	1.18	0.68	0.84
Potash	0.82	0.84	3.53	2.13	2.44	2.30
Soda	0.58	0.76	0.55	0.90	0.91	1.59
Phosphoric acid	N. E.	N. E.	0.16	.....	.....	.....
Sulphuric acid	N. E.	N. E.	.....	0.25	0.60	0.12

Lawrence County.

Clay parting, seven inches thick, in the Peach Orchard coal, Peach Orchard mines. Collected by A. R. Crandall.

Ignition and moisture	10.32
Silica	55.60
Alumina, with traces of iron oxide	30.04
Lime carbonate	1.74
Potash	0.20
Soda	0.40
	98.30

For a shale clay this compares favorably with the fire-clays.

Lincoln County.

No. 1873.—"Clay, from the headwaters of Green River, on the land of Mr. Thos. W. Varnon. Bed two to four feet from the surface, and said to be forty-two to forty-five feet thick; resting on black shale which is fifty feet thick. Salt water is found by boring, at the depth of eighty-four feet, and some little petroleum in the sandstone. Sent by Senator Varnon."

Clay imperfectly laminated, of a dark olive-grey color. Fuses before the blow-pipe. Burns of a grey-buff color.

The considerable proportions of the iron-oxide, lime, potash and soda prevent this clay from being refractory in the fire. But while it is, therefore, unfit for the manufacture of fire-bricks, it will yet answer well for ordinary pottery, terra cotta work, or tiles.

Following is the analysis of this clay:

Ignition and moisture	5.70
Silica	61.58
Alumina	23.94
Ferric oxide	5.81
Lime	0.20
Magnesia	0.85
Potash	1.54
Soda	0.36
	99.98

For analyses of other Lincoln county clays see Part II. of this bulletin.

Madison County.

No. 1876 (*a*).—"Potter's Clay (quality No. 1). Upper Silurian. Waco, nine miles east of Richmond. Collected by A. R. Crandall."

A light-grey soft clay, with some ochreous stains and infiltration.

No. 1876 (*b*).—"Potter's Clay (quality No. 2). Same locality as above. Of a bluish-grey color."

No. 2496.—Shaly Clay. "From land of James Walker (F. W. Lewis), two miles south of Bobtown, about one hundred yards to the left of Big Hill Turnpike, almost opposite Lewis blacksmith shop. Bed four to five feet thick. Sample of the upper ten inches. Collected by Moritz Fischer, June 21, 1884."

A laminated clay or soft shale, of a light-grey color on the exterior; darker colored and brownish-yellowish-grey in the interior.

No. 2497.—Shaly Clay. "From same locality as the preceding. etc. Sample from ten to twenty inches below the surface. Collected by M. Fischer."

Darker colored than the preceding; of a light olive-green color.

A small quantity of titanic acid was found in No. 2497, but 2496 was not tested for this substance.

No doubt comon pottery and terra cotta could be made of this clay, ground and properly tempered with water. It contains too much potash, lime and iron oxide for the fire-clay.

If its potash were not in close chemical combination with the other elements of this clay, it might be useful as a fertilizer. Its only profitable application for this purpose would be to a very light sandy soil not far distant from the clay, as it would not pay for distant transportation.

No. 2498.—Plastic Clay. "From the land of Gordon Glasgow, slope of Bare Knob, three miles south of Berea. Waverly clay, near the Conglomerate. Collected by Moritz Fischer, July 1, 1884."

A light-grey, plastic clay. Calcines of a light-reddish color. Fuses before the blow-pipe. This clay could be used for the manufacture of various kinds of common pottery, terra cotta products, etc.

No. 2499.—Marly Shale. "On the land of John Pigg, four miles northeast of Berea, near the road from Berea to the Big Hill Turnpike, by the way of Bobtown. The locality is called Blue Lick. Waverly formation, resting on black shale. Said to be a good fertilizer on black shale and Waverly soils. Collected by Moritz Fischer, August 16, 1884."

As experience seems to have demonstrated to a certain extent this shale might be advantageously applied as a top-dressing to poor, sandy soils. But it would not pay to transport it to any considerable distance, especially because its potash, although in quite notable proportion, would be slowly available, being in pretty firm combination with the silicates; and moreover, its phosphoric acid is in small proportion. Exposed to moisture, frost and the atmospheric agencies generally, it would soon disintegrate into a clay. Pulverized and kneaded with water, it would be plastic enough to be used for common pottery ware.

No. 2186.—"Marly shale; on the road near A. Lake's place; 300 yards west of Drowning creek. 'Niagara Group.' Collected by John R. Procter."

An olive-grey and brownish-grey, somewhat firm shale, mottled in parts; adhering to the tongue. Quite plastic with water when powdered. Calcines of a light brick color. Fuses before the blow-pipe into a dark brown, nearly black slag.

No. 2187.—"Marly shale or indurated marly clay. On the hill two hundred yards north of Dr. Freeman's dwelling. Probably the same bed as No. 2170 found below, beneath the Corniferous limestone. The bed is six feet thick or more, and contains gypsum. Collected by John R. Procter."

Generally in thin, soft, irregular laminae, of a light olive-grey color, irregularly varied with brownish yellow or ochreous. It contains gypsum in irregular crystals between some of the laminae; shows some fossil vegetable impressions, probably fucoid, on some of the layers.

Because of the large proportion of gypsum (plaster of Paris) contained in No. 2187, and its considerable quantity of potash, it would no doubt prove a valuable top dressing on soil and crops where the use of plaster is indicated. Shale No. 2186 would be useful on soils principally on account of the lime which it contains, which is equivalent to nearly 24 per cent. of carbonate of lime.

No. 2168.—"Clay; Milton Barlow; from near Bybeetown. Bed four feet thick; in black shale." Collected by John R. Procter.

Clay of a light, drab-grey color. Irregularly and imperfectly laminated. Quite plastic. Burns of a delicate light, reddish-cream color, nearly white. Before the blow-pipe it fuses into a whitish slag with difficulty.

No. 2169.—"Clay of workable thickness; on the road leading from Waco to R. Oldham's, about a mile and a half from Waco. Probably below the Corniferous limestone. Collected by John R. Procter."

A compact clay, generally of a light, olive grey color, stained irregularly with ochreous spots. Quite plastic. Calcines quite hard of a handsome light brick color. Before the blow-pipe, it fuses into a brownish-grey slag.

No. 2170.—"Indurated Clay; farm of C. L. Searcy, near Elliston. Beneath the Corniferous Limestone. Bed ten feet thick or more. Makes a good soil." Collected by John R. Procter.

A light, olive-grey, laminated clay, mottled with ochreous or orange-colored ferruginous infiltrations. The laminae are contorted. It is quite plastic. Burns of a handsome flesh-color. Fuses into a grey slag before the blow-pipe.

These are good plastic clays for the manufacture of ordinary pottery ware, as well as for ornamental articles of terra cotta, for which use they are adopted because of the pleasant tints they assume in calcination. They owe these tints to their considerable proportion of iron oxide, which, together with their large proportion of potash, renders them unavailable as fire-clays. This very circumstance, however, may fit them for stone-ware, and for superior kinds of hard, burnt, semi-fused, ornamental pottery in the hands of skillful workmen and artists.

Following are the analyses of these Madison county clays, etc.:

	No.	Ignition and Moisture	Silica	Alumina	Ferric Oxide	Lime	Magnesia	Potash	Soda
Madison	1876(a)	7.02	59.97	27.64	In Al.	0.28	0.60	3.93	0.54
Madison	1876(b)	10.53	56.96	28.74	In Al.	0.20	0.75	2.50	0.31
Madison	2496	8.09	59.00	24.64	In Al.	1.45	1.09	5.50	0.21
Madison	2497	15.54	42.56	20.98	In Al.	8.68	7.24	4.81	0.16
Madison	2498	20.01	48.00	13.38	3.90	1.60	4.03	3.79	0.27
Madison	2459	3.97	68.44	20.18	In Al.	0.14	2.86	3.67	0.74
Madison	2186	16.22	42.30	20.84	4.12	13.32	0.46	2.38	0.35
Madison*	2187	5.87	48.78	17.32	3.24	19.28	0.49	4.76	0.24
Madison	2168	6.97	62.56	24.78	1.80	Tr.	0.31	3.27	0.29
Madison	2169	5.16	64.56	20.16	4.20	0.21	0.64	5.05	N. E.
Madison	2170	4.14	62.58	22.94	3.76	0.56	0.42	5.28	0.30

*The determination of lime in this analysis is as carbonate.

Additional analyses of Madison county clays will be found in Part II. of this bulletin.

Mason County.

No. 1130.—Marl. Labeled, "Earthy portion between the O. iynx beds of the upper blue limestone, edge of Mason and Fleming counties."

A fine-grained, dark-greenish-grey rock. Not adhering to the tongue. Dried at 212 degrees F., it lost 0.40 per cent. of moisture. It might be used with advantage on exhausted land.

Following is the analysis of this marl, sample dried at 212 degrees F.:

Ignition and moisture	0.791
Silica and insoluble silicates	78.180
Alumina and ferric oxide	8.020
Lime carbonate	7.380
Magnesia	3.105
Potash	0.722
Soda	0.170
Phosphoric acid	1.040
Sulphuric acid	0.592
	100.000

Analyses of other clays and shales of Mason county will appear in a subsequent bulletin.

Meade County.

No. 10804.—Calcareous Marl, sent by J. R. Willett, of Brandenburg. A nearly white material, resembling clay in appearance. Analysis by A. M. Peter, 1903.

No. 10911.—Clay, sent by J. R. Willett, Brandenburg, from bank of creek near the Ohio river, about ten miles below Brandenburg. Analysis by A. M. Peter, 1903.

Analyses of air-dried samples:

	No. 10804	No. 10911
Moisture	1.35	2.04
Combined water, etc.	29.92	6.45
Silica	23.79	64.24
Alumina	6.57	17.03
Ferric oxide	2.02	6.12
Lime	34.73	1.20
Magnesia	1.81	0.57
Potash	.....	0.78
Soda	.....	0.37
Sulphuric acid	0.25	0.03
Phosphoric acid	trace	.....
	100.44	98.83

Commenting on No. 10804, Dr. Peter says: "This material contains nearly twice as much silica, in proportion to the alumina and lime (the latter being equivalent to 62 per cent. of carbonate of line), as is required to make Portland cement; but it might be used in combination with a clay very rich in alumina and a pure limestone." The clay, No. 10911, is suitable for use in making Portland cement.

Analyses of other Meade county clays, marls and shales will appear in a subsequent bulletin.

McLean County.

Clay from under the coal worked by the Green River Coal and Mining Co., Island. A dark grey clay, with polished surfaces and plant impressions. Thickness, four feet. Collected by H. P. McDonald, in 1903. Analysis of air-dried sample by Dr. A. M. Peter:

	Per cent.
Moisture	4.51
Combined water, etc.	7.86
Silica	54.83
Alumina	20.32
Ferric oxide	4.66
Lime	1.42
Magnesia	1.64
Potash	3.52
Soda	0.72
Sulphur	2.04
Titanic oxide	0.45
	101.97

The clay runs high in iron, sulphur and alkalies. It will not serve for fire-bricks.

Muhlenberg County.

No. 1613.—Clay. "From Ross Coal Mines, Owensboro Junction. (Fireclay below the coal in the lower drift.) Collected by C. J. Norwood."

A dark-grey, soft, shaly clay.

Much of the sulphur and iron doubtless exist in the clay, not as sulphuric acid and iron oxide, but in combination, as iron sulphide. The considerable proportions of potash, lime, magnesia, and iron oxide may prevent this from being a very refractory clay; although it may very well answer for the manufacture of stoneware and ordinary fire-bricks.

Following is the analysis of this clay:

Water and ignition	4.19
Silica	63.18
Alumina and iron oxides	26.28
Lime	0.20
Magnesia	0.25
Potash	2.00
Soda	0.42
Phosphoric acid	0.17
Sulphuric acid	3.28

Nelson County.

No. 1189.—Marly Clay. Labeled, "White Clay (or sub-soil)' near the road on the farm of Mr. Stephen Cambron. South of

the 126th mile of Base Line, Nelson county. (Procured by S. S. Lyon.)"

A greyish-white clay, mottled with yellow.

No. 1190.—Clay. Labeled, "Yellowish Clay (or sub-soil), found immediately under the preceding, etc."

A brownish-yellow, ferruginous clay, or sub-soil.

These clays might probably be used with advantage on soil, in their immediate neighborhood, which has been exhausted by long culture or which is deficient in lime, alumina, phosphoric

No. 2216.—"Marly clay, at the base of the Carboniferous series; probably on the Keokuk horizon. Part of the section contains thin beds of clay iron-stone; but beds of many feet in thickness can be obtained. Nelson county. Collected by N. S. Shaler."

This clay is quite plastic, when powdered, and calcines of a buff color. Before the blow-pipe it fuses into a dark-colored slag. This clay may be employed for terra cotta work or other pottery not to be exposed to a very high temperature in burning; but its large proportions of iron oxide, lime, potash, magnesia, and soda cause it to be readily fusible. Its proportion of phosphoric acid was not determined, but its other ingredients, mentioned above, especially the alkalies and lime, may make it a valuable marl for top-dressing light and exhausted soils.

Composition of these Nelson county marls, etc.:

	No. 1189	No. 1190	No. 2216
Water and ignition	12.50	11.30	3.33
Silica	52.68	54.28	61.10
Alumina	12.96	15.34	18.20
Ferric oxides	6.74	12.94	6.00
Lime	*a*12.38	1.98	4.90
Magnesia	0.38	1.21	1.54
Potash	2.84	1.37	4.10
Soda	N. E.	0.12	0.82
Phosphoric acid	0.25	N. E.	.....
Sulphuric acid	N. E.	1.08	.....

a. Lime carbonate.

For analyses of other Nelson county clays, see Part II. of this bulletin.

OHIO COUNTY.

No. 2074.—"Indurated Clay, below Coal J., mouth of Brush Run, on Rough creek. Collected by C. J. Norwood."

A dark-grey shaly-clay, with impressions and remains of reed-like leaves, and some ferruginous stains.

No. 2075.—"Clay, from near Elm Lick, on R. B. Thompson's land. Coal Measures. A good deal used in Louisville. Collected by C. J. Norwood."

An irregularly laminated clay, mottled with grey of various tints, and ferruginous infiltrations. Has some imperfect vegetable impressions, and minute glimmering specks of mica.

No. 2076.—"Clay, from Bald Knob Church, Caney precinct, on the Pinchico Road, about two feet below a coal bed. Collected by C. J. Norwood."

In friable lumps, showing imperfect and irregular stratification. Of a light bluish-grey color, with infiltrations ochreous and ferruginous material, occasionally nearly black, especially in the cracks and along the course of rootlets which have penetrated it. Before the blow-pipe it appears to be quite refractory, not fusing, but softening and shrinking somewhat into a hard, porcelain-like, nearly white mass. When not so intensely heated, it burns of a light salmon color.

No. 2076.—Contains 5.3 per cent. of fine transparent colorless sand grains. This seems to be a very good fire-clay.

Following are the analyses of these Ohio county clays:

	No. 2074	No. 2075	No. 2076
Ignition and moisture	5.37	3.75	7.73
Silica	69.26	70.86	62.76
Alumina	16.64	19.24	26.42
Ferric oxide	4.52	3.12	1.58
Lime	Tr.	Tr.	0.32
Magnesia	0.89	0.42	Tr.
Potash	3.10	2.35	0.91
Soda	0.21	0.25	0.26
Phosphoric acid	.....	.....	.....
Sulphuric acid	.....	.....	.....

Clay from under No. 9 coal at Coffman. Thickness, four feet. A dark grey clay with smooth, polished surfaces. Collected by H. P. McDonald, 1903. Analysis of air-dried sample by A. M. Peter:

	Per cent.
Moisture	4.31
Combined, water, etc.	6.86
Silica	58.55
Alumina	22.17
Ferric oxide	3.48
Lime	0.86
Magnesia	0.92
Potash	2.66
Soda	0.74
Sulphur	1.04
Titanic oxide	0.47
	102.06

The iron and sulphur are principally in the form of pyrites.

OWEN COUNTY.

No. 1203.—Marl. Labeled, "Shale, collected from the spring (now dry) supposed to cause milk-silkness. Waters of Dickey's creek; a mile and a half from Benj. Hayden's, Owen county."

A dirty-buff and brownish ferruginous clay-like substance. Following is the analysis of this clay:

Ignition and moisture	8.99
Silica	29.24
Alumina and iron oxides	19.94
Lime carbonate	34.58
Magnesia	5.28
Potash	0.64
Soda	....
Phosphoric acid	0.93
Sulphuric acid	0.37

POWELL COUNTY.

For analyses of Powell county clays, see Part I. of this bulletin.

PULASKI COUNTY.

No. 2427.—Marly Shale. "From south of the Cumberland River, on the line of the Cincinnati Southern Railroad. Collected by W. H. Pettus, October, 1880."

A very friable marlite, generally of a light-chocolate color. Adheres slightly to the tongue. Notwithstanding the rather more than 4 per cent. of potash contained in this shale, it could not profitably be used as a fertilizer, because most of the potash is in firm chemical combination with the silicates, and the proportion of phosphoric acid is very small.

Following is the analysis of this marly shale:

Moisture	4.92
Silicious residue	69.94
Alumina and iron oxides	15.81
Lime	3.47
Magnesia	0.54
Potash	1.66
Soda	0.03
Carbonic acid and loss	3.60
Phosphoric acid	Trace

In the silicious residue (69.94) are 2.36 per cent. potash and .230 soda. Total potash, 4.026, and soda, .263 per cent.

ROCKCASTLE COUNTY.

No. 1951.—"Clay, from Pine Hill coal mines, Rockcastle county. Collected by John H. Talbutt."

A light-grey plastic clay, mottled with ferruginous spots. This clay was only examined for its proportion of alkalies. It was found to contain of potash—3.083 per cent. of dried clay at 212 degrees; soda—0.524 per cent. It therefore would not probably prove to be a very refractory clay.

Analyses of other Rockcastle county clays will appear in a subsequent bulletin.

Rowan County.

No. 2625.—Shale from the stripping of the Rowan County Freestone Company's quarry at Farmers. The shale lies immediately above the stone. Thickness, forty-two inches. Average sample of hard, dark gray shale, somewhat soapy to the touch. Geological position, Waverly. Analysis of air-dried sample by A. M. Peter, 1905.

No. 2626.—Mixed Shale, lying above No. 2625, with an interval of ten feet between the two. Thickness, four to ten feet. An average sample of mostly greenish rather soft shale, but with some brown shale. Geological position, Waverly. Analysis of air-dried sample by A. M. Peter.

	No. 2625	No. 2626
Moisture	1.07	1.02
Ignition (combined water, etc.)	6.47	6.25
Silica	59.64	59.44
Alumina	21.49	18.93
Ferric oxide	4.22	6.59
Lime	0.28	0.36
Magnesia	1.19	1.30
Potash	3.51	3.45
Soda and trace of lithia	0.47	0.42
Titanic oxide	1.25	1.25
Sulphur trioxide	trace	trace
	99.59	99.01

Each sample should make good brick, either paving or builders', if properly prepared and burned.

Union County.

No. 220.—Marl. Labeled, "Marl, taken from a bed four feet thick, overlying a bed of coal eleven inches thick, near the top of a hill, on the land of Francis H. Shouse, Union county, Ky."

In greenish slate-colored lumps, containing fragments of encrinal stems, small cyathophilli, pieces of fossil bi-valve shells, and fragments of small coral stems.

Ont thousand grains, washed with water, with careful trituration in a mortar, left 598 grains of mixed sand and fragments of fossils, of which 309 grains, principally of fine sand, passed through fine bolting cloth. Dried at 400 degrees, this marl lost 1.92 per cent. of moisture. This might be used as a top-dressing to increase the fertility of poor, silicious, or exhausted soils in its neighborhood, but would not pay its carriage for any great distance.

Following is the analysis of this Union county marl:

Moisture and ignition	7.06
Silica	32.67
Alumina and iron oxides	6.70
Lime carbonate	50.85
Magnesia	0.69
Potash	0.31
Soda	0.16
Phosphoric acid	0.28
Sulphuric acid	1.36

No. 2583.—Soft, light-brown, calcareous material, labeled "From Bald Hill, near the 'Foot Print Rocks,' Union county, Ky. Shows thickness of about fifty feet. Collected July 14, 1904, by C. J. Norwood." Analysis of air-dried sample by A. M. Peter.

The material was in the form of powder and soft, chalky lumps. It was easily made to pass through a 40-mesh sieve without grinding, leaving only a few fragments of snail shell and a few small, tubular casts.

Analysis of the air-dried sample:

	Per cent.
Moisture	0.88
Ignition (carbonic acid, combined water, etc.)	13.95
Silica	57.16
Alumina	7.84
Ferric oxide	2.40
Lime	9.28
Magnesia	5.71
Potash	1.70
Soda	1.00
Titanium dioxide	0.50
Phosphates, sulphates and nitrates	traces
Total	100.42

Chemist's remarks: "The lime present (9.28 per cent.) is equivalent to 16.57 per cent. of calcium carbonate. The ratio of alumina and ferric oxide to silica is too wide for Portland cement, but this material might be used for that purpose in connection with a clay containing much alumina and a limestone free from magnesia. On account of the very fine sand it contains, this material might be used as a polishing powder. It could be of some value as an agricultural marl on land needing lime or inclined to be sour."

Warren County.

No. 2798.—Marl from near the bottom of the St. Louis Limestone beds, near Bowling Green, about 100 feet above Barren River. Sample from the top, middle and bottom of a four-foot bed. Average sample. Collected by M. H. Crump, Civil Engineer, April 30, 1885.

Of a light grey color, portions with ferruginous stains. Plastic with water. Powder of a light buff color. Calcines nearly white, with a light reddish tint.

This marl would be beneficial as a top-dressing to light sandy soil which is deficient in lime. It could also be, no doubt, converted into water cement of the character of Portland, by proper admixture with more lime and calcination. This marl may be said to contain a little more than 43 per cent. of clay (exclusive of moisture), and nearly 44 per cent. of carbonate of lime. Good artificial Portland cement is said to be made in England, etc., from a mixture of 21 to 23 per cent. of clay and 77 to 79 per cent. of chalk (which is nearly pure carbonate of lime). Ground limestone could be used, the best proportions being found by actual experiment.

Following is the analysis of this Warren county marl:

Moisture and ignition	4.17
Silica	28.78
Alumina	11.63
Ferric oxides	2.96
Lime carbonate	43.76
Magnesium carbonate	6.32
Potash	2.12
Soda	N. E.
Phosphoric acid	0.24

WHITLEY COUNTY.

No. 2522.—Bituminous Indurated Clay. "From a bed about five feet thick, which has, near its center, a four-inch streak of what seems to be iron carbonate containing bright specks of pyrites. On the line of the Knoxville branch of the L. & N. R. R., near Brummitt's Station. Sample sent November 20, 1883, by Thos. W. Varnon, Esq., Mount Sterling, Ky."

A soft shale or indurated clay, of a dark slate color, with some minute specks of mica, and in one of the pieces an impression of a reed-like leaf. Breaks in irregular, imperfect laminae; is soft enough to be scratched by the nail. Does not soften much in water unless when pulverized, when it forms a very tough, plastic clay. Before the blow-pipe it fuses with difficulty into a yellowish-grey, blebby mass.

It would answer, no doubt, for the manufacture of stoneware, as it burns of a buff-grey color, and many terra cotta and other varieties of pottery could be made of it. It contains too much potash, soda, lime, magnesia and iron oxide for a fire-clay.

No. 3034.—Clay; from a bed five feet thick, on Indian creek. Sample collected by A. R. Crandall, March, 1889.

A friable, indurated clay, of a buff-grey color. Refractory before the blow-pipe.

No. 3035.—Clay. "Jellico Clay," Whitley county and Tennessee. A white indurated clay. Refractory before the blow-pipe.

Both these clays are good fire-clays. The large proportion of silica in No. 3035 would make it quite refractory.

Following are the analyses of these Whitley county clays:

	No. 3034	No. 3035
Moisture and ignition	6.56	1.56
Silica	59.10	84.76
Alumina	29.76	11.40
Ferric oxides	Tr.	Tr.
Lime	Tr.	Tr.
Magnesia	0.72	0.65
Potash	3.86	1.58
Soda	Tr.	0.05