Mississippi State Geological Survey

ALBERT F. CRIDER, DIRECTOR.

BULLETIN No. 2

THE

CLAYS OF MISSISSIPPI

By WILLIAM N. LOGAN

BRANDON NASHVILLE

Mississippi
State Geological Survey

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PART I.

Brick Clays and Clay Industry of Northern Mississippi

By WILLIAM N. LOGAN

BRANDON-NASHVILLE

STATE GEOLOGICAL COMMISSION.

His Excellency, James K. Vardaman	*Governor*
Dunbar Rowland	*Director of Archives and History*
A. A. Kincannon	*Chancellor of the State University*
J. C. Hardy	*President Agricultural and Mechanical College*
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GEOLOGICAL CORPS.

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LETTER OF TRANSMITTAL.

STATE GEOLOGICAL SURVEY.
JACKSON, MISSISSIPPI, July 20, 1907.

To Governor James K. Vardaman, Chairman, and Members of the Geological Commission:

GENTLEMEN—I submit herewith a report on the clays and clay industry of northern Mississippi by Dr. William N. Logan, and respectfully recommend its publication.

Very respectfully,

ALBERT F. CRIDER,
Director.

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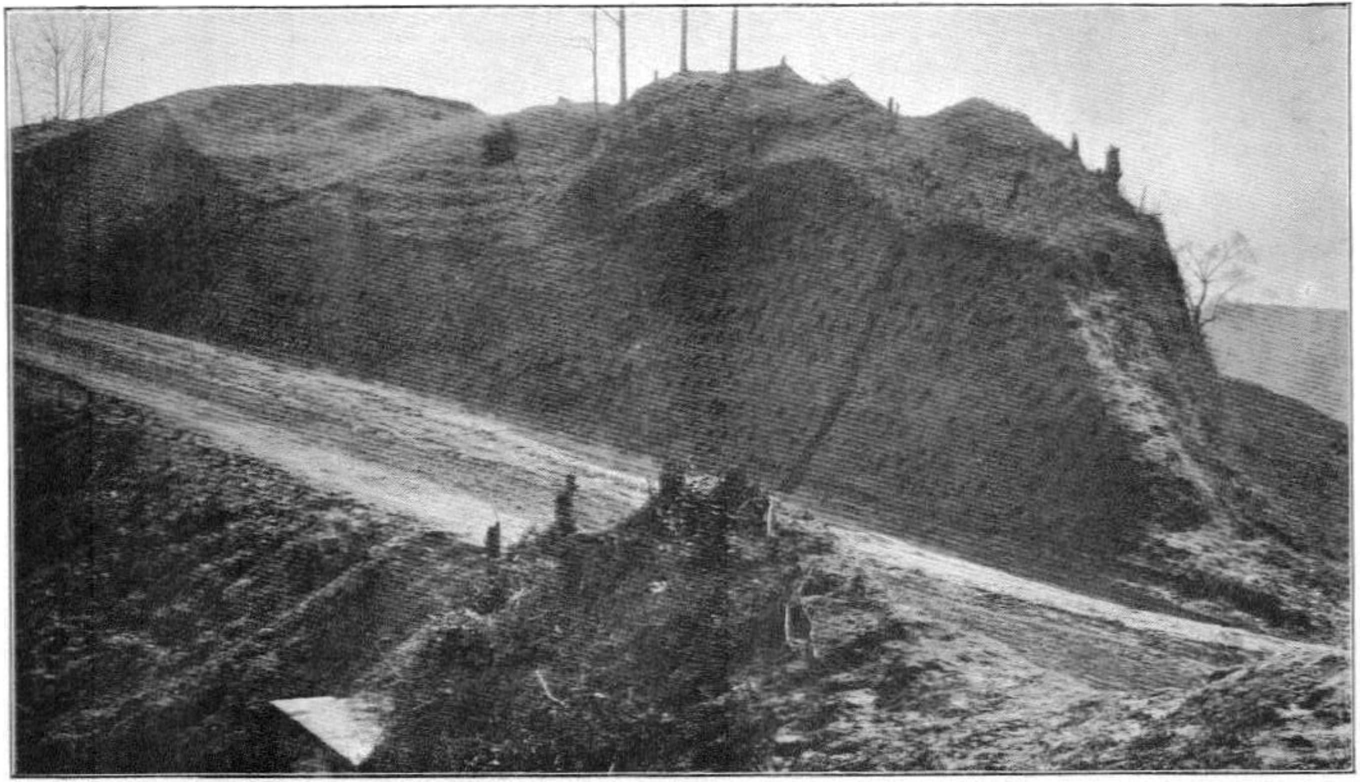


MANTLE ROCK RESTING ON BED ROCK, VICKSBURG. ALL ROCK ABOVE ROADBED IS MANTLE ROCK.

CHAPTER I.

ORIGIN AND CLASSIFICATION OF CLAY.

POSITION AND RELATION OF CLAY TO OTHER EARTH MATERIALS.

Structurally the known and knowable portion of the earth may be divided into three great spherical envelopes. An outer gaseous sphere, the atmosphere; a liquid sphere, the water sphere or hydrosphere; and a solid rock sphere called the lithosphere.

LITHOSPHERE.

The lithosphere consists of a loose mantle of earthy material, the regolith, at the surface and a more compact, indurated substratum, the durolith, to which the term "bed rock" is often applied.

Regolith.

The regolith consists of unconsolidated beds of sand, gravel, pebbles, bowlders and clay, or of mixtures of these together with organic matter forming loams, marls, peat, and soils. The regolith varies in thickness from a few inches to several hundred feet. It is often but the residual product resulting from the weathering of the bed rock. Its thickness, therefore, may represent the amount of bed-rock decay that has taken place at that point or it may represent the amount of decay which has taken place on some neighboring higher area, the debris of which has been transported to this point.

Durolith.

The durolith consists of beds of consolidated and more or less indurated rocks such as shale, sandstone, limestone, coal, granite and marble. In some regions the durolith is completely concealed by the regolith so that it may be studied only by means of deep cuts and the records of wells which pierce its strata. As to the thickness of the durolith we have little knowledge. The most profound excavations of Nature do not descend to depths much greater than one mile. The deepest excavations or borings made by man transcend this limit only by a small degree. Therefore, our knowledge of the thickness of the crust of the earth, as well as our knowledge of its internal mass, we gain only by inference.

Rocks of the Regolith.

The mantle rocks are unconsolidated fragments of rock waste and organic decay forming sand, clay, marl, loess, and gravels.

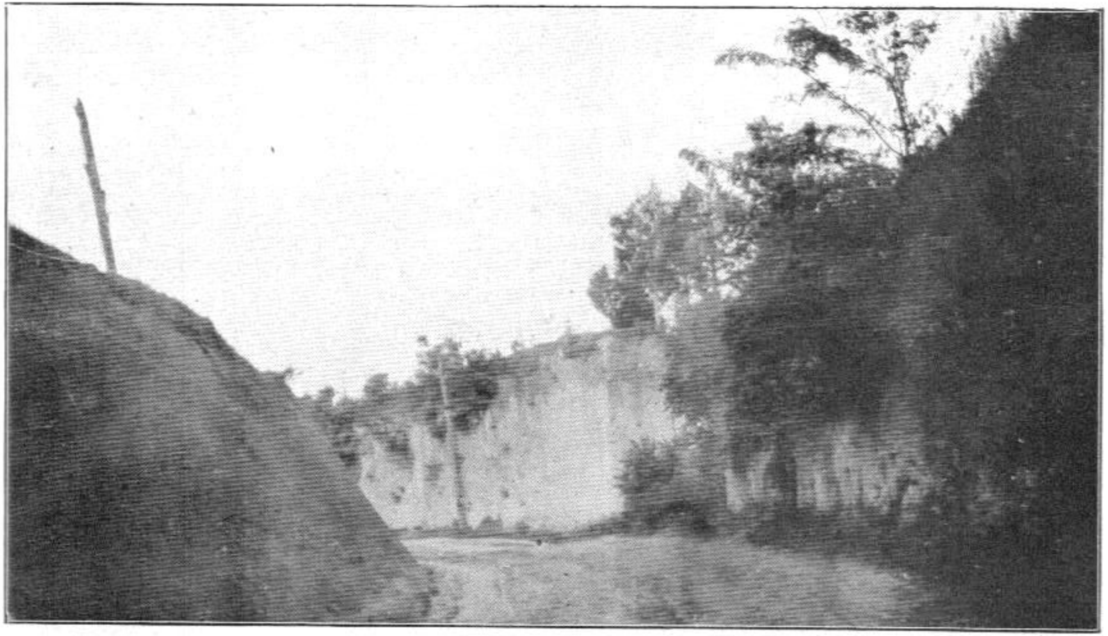
Sand.—Sand is composed of hard particles, usually of quartz, though sands of feldspar, magnetite, mica, gypsum and other minerals are not uncommon. Most quartzose sands contain at least small quantities of some of these minerals. The individual grains of sand may have sharp edges and irregular forms. These are generally particles which have not been eroded by transportation. Sharp sands are for the most part residual sands. Transported sands are more regular in form and have a rounded surface, or sub-angular edges. The size of the sand particles are extremely variable. They range from the coarseness of gravel to the impalpability of dust. In color there exists a multiplicity of tints and shades. In some sands the coloring matter is inherent; in many, however, it is due to the presence of an enclosing film of pigment such as oxide of iron.

Clay.—Clay is a soft rock which is usually smooth or greasy to the touch. When mixed with the proper proportion of water it may be readily molded into desired forms which will have the power of retaining their shape. This property, plasticity, is not possessed in a high degree by other rocks and is therefore one of the determinative characters of clay. Clay is a mechanical mixture of minerals. The proportion of these mineral constituents may vary; hence the composition of clays varies greatly. Aluminous clays are those containing a large quantity of the mineral kaolinite, which is the basis of all clays. Arenaceous clays contain a large quantity of sand. Calcareous clays contain much carbonate of lime. Ferruginous clays are those containing considerable proportion of some iron compound.

Loess.—Loess is a silty material composed of very fine particles of clay, sand, limestone and other earthy materials and also some organic matter. In cuts and excavations it tends to maintain vertical faces and a columnar structure. In many places it contains irregular concretions of calcium carbonate and the shells of species of gastropods.

Marl.—Marl is a mixture of clay, sand, and limy material. Shell marl is a mixture of clay, sand and the shells and bones of animals, such as snails, mussels, fish and oysters. Marls may be of marine

Plate II.



ROADBED IN THE LOESS, NATCHEZ.

origin formed under sea water or they may be of lacustrine origin, formed in lakes.

Peat.—Peat is a dark substance composed mainly of vegetable matter which has undergone changes under water. It is formed by the accumulation of vegetable matter in lakes, ponds and marshes. Its amount of organic matter depends inversely upon the amount of earthy matter deposited with the vegetation.

Gravel, Pebbles and Bowlders.—Gravel, pebbles and bowlders are fragments of hard rocks of sizes varying from a pea in gravel and pebbles, to rounded fragments several feet in diameter in bowlders. Since this material can be transported only by streams of high velocity, these deposits are usually found where such streams suddenly lose their velocity. Mountain streams which descend to plains deposit such rocks.

Rocks of the Durolith.

The rocks of the durolith are more compact than those of the regolith. They may exist without planes of division or they may be formed of layers; in the former case they are said to be massive, in the latter to be stratified. Sandstone, shale, limestone, conglomerate, coal, granite, gneiss, marble and slate are some of the more common kinds of bed-rock.

Sandstone.—Sandstone is a rock formed of grains of sand bound together by some cementing substance. The cement may be iron, lime or silica. Coarse sandstones are composed of large sand grains. Where the grains are small the texture of the rock is fine. Sandstones may be massive or stratified. Crossbedded sandstones are those in which the bedding planes do not lie in parallel lines, but in which one set of planes lies oblique to another set. The color of sandstones is usually dependent on the presence of films of coloring matter coating the individual grains.

Conglomerate.—Conglomerate is formed by the cementation of gravel and pebbles. As in the case of sandstone, the cement may be iron, lime or silica. If the pebbles are rounded, the rock is called pudding stone; if the fragments are irregular or angular, the rock is called breccia. Such rocks may be deposited under the sea, in which case they may be identified as marine in origin by the organic remains usually found in them. Many beds of such rocks devoid of organic remains are supposed to have been deposited in lodgement areas upon the land.

Shale.—Shale is compressed clay which has a form of cleavage causing it to split into flakes or blocks. Its physical properties are similar to those of clay, though it is usually harder and more dense. Shale is formed of clay which has been carried by the action of streams from the land and deposited either in the sea or in lakes. After deposition the clay is subjected to the pressure of overlying rocks, and to crustal movements which increase its density and develop its structure. Since the clay particles are smaller and lighter than other rock fragments, they are carried further out. The sorting action may result in beds of marked purity. The color of shales is generally dark or blue and is due to the presence of either some iron compound or of organic matter. The removal of the coloring matter by weathering usually results in lighter colors.

Limestone.—Limestone is composed, for the most part, of calcium carbonate derived from the skeletons of animals. All marine animals secreting either an endo-skeleton or an exo-skeleton may contribute to the formation of such beds. Deposits of coral form one of the chief sources of such lime material. Skeletons of shell-fish dropped within the littoral zone of the sea become broken and the fragments cemented together to form shell rock which by further changes may form compact limestones. Shells of animals of microscopic size form beds of chalk, sometimes of great extent and thickness.

Marble.—Marble is a metamorphic limestone of crystalline nature. Slate may have been formed likewise from the metamorphism of shale.

Granite.—Granite is a crystalline rock of igneous origin. It is composed mainly of varying amounts of feldspar, mica, quartz and hornblende, with very much smaller amounts of other minerals. The crystals are usually of microscopic size and closely interlocked. The color of the granite is largely dependent on the feldspar, which is usually either pink or gray. The disintegration and the decomposition of granite result in the formation of beds of sand and kaolin, the former being derived from the quartz and the latter from the feldspar. Wherever granite under the influence of metamorphic action has become foliated, it forms a rock termed gneiss.

Rocks are usually classed as: (1) fragmental rocks, those formed from the particles of older rocks; (2) igneous rocks, those formed from the cooling of molten magmas; (3) metamorphic rocks, those which have undergone alteration under the influence of heat and pressure.

Fragmental rocks, which are deposited under water, are called aqueous or sedimentary. Those deposited by wind are called eolian rocks. Limestone, sandstone and shale are common examples of fragmental rocks; granite, syenite and gabbro are examples of igneous rocks; while marble, slate and anthracite coal are examples of metamorphic rocks.

Classification of Rocks.

I. Fragmental rocks, also called aqueous or sedimentary, deposited by winds, water and ice on land and in water.

  A. Sand group.
    1. Sand.
    2. Gravel.
    3. Sandstone.
    4. Pudding-stone.
    5. Breccia.
  B. Lime group.
    1. Chalk.
    2. Coquina.
    3. Limestone.
    4. Dolomite.
    5. Marl.
    6. Travertine.
    7. Tufa.
  C. Clay group.
    1. Kaolin.
    2. Clay.
    3. Shale.
    4. Loam.
    5. Loess.
    6. Till.

- II. Igneous rocks, resulting from the solidification of molten magmas.
  - A. Pyroclastic rocks.
    - 1. Volcanic ash.
    - 2. Lapilli and bombs.
    - 3. Tuffs.
    - 4. Scoriae.
    - 5. Pumice.
    - 6. Puzzolana.
  - B. Lavas or glassy rock.
    - 1. Acidic.
      - *a.* Obsidian.
      - *b.* Perlite.
      - *c.* Trachyte.
      - *d.* Rhyolite.
    - 2. Basic.
      - *a.* Basalts.
      - *b.* Dolerite.
  - C. Phanerocrystalline rocks.
    - 1. Acidic.
      - *a.* Granite.
      - *b.* Syenite.
    - 2. Basic.
      - *a.* Gabbros.
      - *b.* Peridotites.
- III. Metamorphic rocks.
  - A. Rocks of sedimentary origin.
    - 1. Marble.
    - 2. Slate.
    - 3. Quartzite.
  - B. Rocks of igneous origin.
    - 1. Gneiss.
    - 2. Schist.

Composition of the Lithosphere.

The rocks of the lithosphere are composed of a large number of minerals, these minerals in turn being composed of elements. To illustrate, calcite ($CaCO_3$), the principal constituent of limestone, is composed of three elements, calcium, carbon and oxygen. These are united in the proportion of one part calcium and one part carbon to three parts of oxygen. More than 70 chemical elements have been discovered in the earth. Eight of these elements form nearly 99 per cent of the solid crust of the earth.

The estimated composition of the solid portion of the lithosphere is given by F. W. Clarke* as follows:

TABLE I.

COMPOSITION OF THE LITHOSPHERE.

Element	*Symbol*	*Per Cent in Crust*
1. Oxygen	(O)	47.02
2. Silicon	(Si)	28.06
3. Aluminum	(Al)	8.16
4. Iron	(Fe)	4.64
5. Calcium	(Ca)	3.50
6. Magnesium	(Mg)	2.62
7. Sodium	(Na)	2.63
8. Potassium	(K)	2.32
9. Titanium	(Ti)	.41
10. Hydrogen	(H)	.17
11. Carbon	(C)	.12
12. Phosphorus	(P)	.09
13. Manganese	(Mn)	.07
14. Sulphur	(S)	.07
15. Barium	(Ba)	.05
16. Strontium	(Sr)	.02
17. Chromium	(Cr)	.01
18. Nickel	(Ni)	.01
19. Lithium	(Li)	.01
20. Chlorine	(Cl)	.01
21. Fluorine	(Fl)	.01
Total		100.00

The last thirteen of these elements comprise only 1.05 per cent of the solid crust, while the precious metals such as gold and silver, and the baser metals such as copper, lead and zinc, constitute such a small percentage of the rocks as to be considered negligible quantities.

As already stated the elements are united to form minerals which make up the rocks of the lithosphere. Oxygen uniting with silicon produces an oxide (SiO_2) which acts as an acid. The acid uniting with bases such as aluminum, potassium and calcium forms silicates, and uniting with other elements it forms oxides of iron, calcium,

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*Analysis of Rocks, Bul. 168, U. S. Geol. Survey, 1900, p. 15.

magnesium, etc. These by the union with acids produce sulphates, chlorides, carbonates and other combinations.

Rock Alteration and Decomposition.

The disintegration of rocks is brought about by the action of two sets of forces. The internal dynamical forces of the earth produced by the loss of heat and consequent shrinkage of the earth, result in faulting, folding, oscillation and deformation, accompanied by vulcanism and earthquakes. These movements disrupt the rocks and contribute to their decay.

The forces of the atmosphere, the hydrosphere and the life sphere are agents of destruction. Air which contains nitric acid, carbon dioxide, oxygen and watery vapor is an active agent of rock decay. Fresh faces of rocks soon lose their brightness and freshness under the corroding effect of the atmosphere.

Sudden changes of temperature set up strains in rocks which they are not able to withstand and consequently they are broken up, and their fragments exposed to other weathering agents. The wind catching up particles of rocky material blows them with violent force against the surfaces of rocks and wears them away.

Water running over the surface of rocks wears them by means of the rock particles which it carries with it. Falling water beats upon and erodes the surface of soft rock. Waves erode the rocks on the shores, breaking them apart and using the fragments as tools for further destruction. Water also exerts a chemical action on rocks. Some rocks may be dissolved by pure water but others are soluble only in waters containing acids.

Limestones which yield readily to the action of acid-bearing waters are dissolved and carried away in large quantities by surface and underground waters which contain acids derived from decomposing mineral and organic matter. Caverns, sink-holes, and underground streams and passages which represent the dissolved and eroded portions of limestone beds are generally characteristic of limestone regions. Carbon dioxide formed by plant decay and collected from the atmosphere by falling water is one of the most important solvents.

In the presence of moisture oxygen becomes an effective agent of rock decay. Compounds of iron in the rocks are attacked by oxygen and decomposed, thus contributing to the decay of the rock.

The process of oxidation may be accompanied by the process of hydration, in which case the oxidized mineral takes up water. Hydration usually produces a softer mineral, one more easily eroded and thus weakens the rock.

Roots of trees growing in crevices exert a mechanical action which splits the rocks apart, and a chemical action which dissolves them by virtue of vegetable acid from the roots. Man by digging wells, excavating tunnels and cultivating the soil also breaks up the rocks.

The decomposition and the alteration of rocks containing silicates of aluminum is the source of clay. The group of silicates known as feldspars constitutes the most fruitful source of clay. Feldspar is one of the principal constituents of granite and other igneous or metamorphic rocks of the granitoid group. For this reason the formation of residual deposits of clay is closely associated with the disintegration of granite and the subsequent alteration of its silicate minerals.

The disintegration and decomposition of granite is accomplished by the various mechanical and chemical agents which are actively engaged in rock weathering. The alteration of the silicates is accomplished by the action of mineral and vegetable acids carried through the pores of the rock by circulating waters.

One of the most destructive of these acids is carbonic acid (H_2CO_3). This acid first attacks the potash and soda, hence silicates containing these bases are the first to be broken up. Lime and magnesia compounds are next attacked, then the silicates containing iron, and lastly the aluminum silicates, the most stable of the compounds. These complex compounds having been broken up into their component elements, reactions between the elements occur and new compounds are formed. Aluminum uniting with silicic acid forms new silicates which are free from the other bases, and, since they are more readily soluble, are carried away by circulating waters.

The aluminum silicates thus formed are kaolinite, cimolite, halloysite, collyrite, schrötterite, etc.; also some oxides or hydroxides of alumina, such as gibbsite. These aluminous minerals form beds of rock called kaolin. Kaolin is the basis of all clays. The purity of a clay depends upon the percentage of kaolin which it contains. The higher the percentage of kaolin the purer the clay.

The other minerals which are usually associated with kaolin in clays are quartz, calcite, hematite, siderite, limonite, pyrite, feldspar, mica, rutile, lignite and dolomite. The kind and the quantity of these mineral impurities affect greatly the usefulness of the clay. The impurities may have originated from the decomposition of the rock which formed the clay, or they may have been deposited with the clay during a process of transportation and deposition, or they may have been deposited in the clay by circulating waters. The quantity of kaolin present and the amount and nature of the impurities serve as a guide to the uses for which clay may be employed, but the physical properties of the clay must also be considered.

Origin of Clay.

The origin of kaolin has been suggested in the foregoing pages. We have now to consider the origin of the various deposits of clay which are found in the rocks of the lithosphere. The following outline suggests a method of classification of clay deposits according to their origin:

I. Residual clay.
    A. Clays derived from igneous rocks.
        a. Kaolin derived from granite and other feldspathic rocks.
        b. Ferruginous and impure kaolin derived ordinarily from igneous rocks containing hornblende and other ferromagnesian minerals.
    B. Clays derived from metamorphic rock.
        a. Kaolin derived from gneiss and from other feldspathic metamorphic rocks.
        b. Impure kaolin or clay derived from slate, schist or argillaceous marbles.
    C. Clays derived from sedimentary rocks.
        a. Surface clay derived from shale.
        b. Surface clay derived from argillaceous limestone.
        c. Surface clay derived from argillaceous sandstone.

- II. Transported clays.
  - A. Fluvatile clays, those transported by streams.
    - *a*. Delta clays, those deposited in deltas.
    - *b*. Estuary clays, those deposited in the broad mouths of rivers.
    - *c*. Flood-plain clays, those deposited on the flood plain of rivers.
  - B. Lacustrine clays, transported and deposited in lakes.
  - C. Marine clays, transported and deposited in marine waters.
    - *a*. Unconsolidated beds of clay.
    - *b*. Shales, compact laminated clays.
  - D. Glacial clays, those transported by ice.
    - *a*. Till.
    - *b*. Loess (in part).
  - E. Eolian clays, transported by winds.
    - *a*. Loess (in part).
    - *b*. Adobe clays.

Residual Clay.—Residual clays are beds of kaolin or the more common varieties of clay formed in place by the decomposition of other rocks. As has already been stated the disintegration of the rocks is brought about by weathering. The alteration of the constituent minerals is accomplished by acids carried by meteoric waters. The depth to which kaolinization may take place is necessarily limited to a thin outer zone of lithosphere. Very rarely such deposits are of greater thickness than 100 feet, and the greater majority would fall within the limit of a fourth of that thickness.

In exceptional cases kaolinization is thought to be produced by ascending solutions. Under such conditions the deposits may extend to depths greater than those produced by the action of surficial agents. The following table, compiled from Merrill's Rocks, Rock Weathering and Soils, pp. 215–17, illustrates the loss of constituent minerals which crystalline rocks may suffer during decomposition:

TABLE 2.

LOSS OF CONSTITUENT MINERALS IN THE DECOMPOSITION OF CRYSTALLINE ROCKS.

	GNEISS		PHONOLITE		SYENITE		
Constituent	*Fresh*	*Decomposed*	*Fresh*	*Decomposed*	*Fresh*	*Decomposed*	
Silica (SiO_2)...........	60.69	45.31	55.67	55.72	59.70	58.50	46.27
Alumina (Al_2O_3)......	16.89	26.55	20.64	22.19	18.85	25.71	38.57
Iron oxide (Fe_2O_3)....	9.06	12.18	3.14	3.44	4.85	3.74	1.36
Lime (CaO)...........	4.44	Trace	1.40	1.28	1.34	.44	.34
Magnesia (MgO).......	1.06	.89	.42	.44	.68	Trace	.25
Potash (K_2O).........	4.25	2.40	5.56	6.26	5.97	1.96	.23
Soda (Na_2O)..........	2.82	1.10	7.12	2.65	6.29	1.37	.37
Phosphoric acid (P_2O_5)	.25	.47	.....	.....	.....	.....	.....
Ignition...............	.62	13.75	4.33	7.79	1.88	5.85	13.61
Total............	100.08%	99.98%	98.28%	99.77%	99.56%	97.57%	101.00%

The first analysis under decomposed syenite represents the first stage in decomposition, while the second analysis represents the last stage in which a kaolin-like residue is produced. The increase in the amount of alumina in all the decomposition products is very noticeable.

Residual clays also result from the decomposition of some limestones and sandstones. Limestones containing just a small per cent of clay will often form clay beds of appreciable thickness through long continued decomposition. Calcium carbonate is dissolved out by meteoric water containing acids and the insoluble clay accumulates. The cementing material of sandstones is dissolved and sand particles and clay particles thus freed are separated by the sorting action of running water. The following analyses of limestone and the residual product exhibit the loss of constituent minerals by decomposition:

TABLE 3.

LOSS OF CONSTITUENT MINERALS IN THE DECOMPOSITION OF LIMESTONE.

	LIMESTONE 1		LIMESTONE 2		LIMESTONE 3	
Constituent	*Fresh*	*Decomposed*	*Fresh*	*Decomposed*	*Fresh*	*Decomposed*
Silicon dioxide (SiO_2).........	32.81	63.63	20.60	65.30	17.03	76.60
Aluminum oxide (Al_2O_3)	11.15	10.34	7.63	12.63	21.00	18.37
Iron oxide (Fe_2O_3)	4.65	8.75	4.62	12.18	3.33	2.00
Calcium oxide (CaO).........	22.69	3.75	41.81	1.50	29.29	.90
Magnesium oxide (MgO)......	1.53	.50	.81	.63	.....	.....
Sulphur trioxide (SO_3).......	1.55	.34	.25	.25	.72	.70
Moisture (H_2O)..............	2.75	4.25	.85	4.75	.75	.55
Volatile matter (CO_2etc.).....	22.61	7.77	23.15	2.27	28.20	.97
Total..................	99.74%	99.33%	99.72%	99.51%	100.32%	100.09%

These samples were taken from the Selma chalk and the residual clay overlying it.

Transported Clay.—The residue formed by the decomposition of rocks may not be allowed to remain on the surface where it was formed. By the action of gravity, of water, of wind, or of ice it may be transported and deposited at some distant point. The particles of such residium accumulating upon a slope will, influenced by gravity, gradually creep to the bottom of the slope. The water which falls upon the slope and runs away to the lower levels to form the rills, brooks and larger streams becomes filled with the finer particles, the size of the particles carried being dependent on the velocity of the water, which in turn is dependent upon the slope. A stream having a velocity of only one-third of a mile an hour is sufficient for the transportation of clay particles. Because of the minute size of the particles and their light weight, clay is one of the first materials to be taken away from a residual deposit by running water. Whenever the stream carrying the particles retards its velocity, it drops its load in proportion to the loss of velocity. A small decrease in velocity will cause the loss of only the coarser particles. A sudden and complete loss of velocity would mean the deposition of all sizes of the materials held in suspension. The presence of coarse sand in clays may thus be explained. Rivers may carry fine particles of rock material to lake or sea and as the waters of the stream mingle with the waters of the larger body they lose their velocity and deposit their load. Thus it is that estuary and delta deposits are formed. Carried by ocean currents and redeposited on the sub-aqueous coastal shelf, beds of marine sands and clays are formed, the coarser material being deposited nearest the shore. Deposits of sand, silt and clay are made on the flood-plains of rivers during the overflow periods. The coarser material is thrown down near the banks of the stream, where the water on leaving the channel loses the greater part of its velocity and therefore its capacity for carrying suspended matter. The finer material is carried farther from the channel and, by the sorting action of water, beds of almost pure clay, the finest material, may be found upon the flood-plain.

Lacustrine clays are clay deposits formed along the shores and on the bottom of lakes, the material of which is derived from the land and carried in by streams. In a similar way marine clays are formed on the ocean bed. When these clay beds, in the course of deposition, become deeply buried under other deposits they become compacted into a firm clay rock called shale.

During the glacial period vast quantities of rock material were transported by ice and deposited in an irregular sheet of mantle rock to which the name "drift" has been applied. The drift contains in many places beds of clay called till. Streams of water coming from the front of the melting glaciers carried away the fine particles of clay and rock flour and spread them in some places over large areas. This fine, silty material is called loess. Part of the loess was transported and redeposited by winds, thus producing our second form of loess deposits under the head of eolian deposits. Adobe clays of the plains are thought to be of eolian origin.

Classification of Clays.

Clays may be classified according to their origin, according to their mode of occurrence; according to their chemical or physical properties, and according to their uses. A large number of classifications have been suggested by different writers on ceramics. None of these classifications are wholly free from objections for the reason that it is difficult to arrange a grouping which will be free from overlaps. The following classification was arranged by Wheeler:*

1. White ware.......	Kaolin. China clay. Ball clay.
2. Refractory.......	Plastic fire clay Flint clay. Refractory shale.
3. Potter's............	Plastic clay and shale of moderate fusibility.
4. Vitrifying........	Paving brick clay and shale. Sewer pipe clay and shale. Roofing tile clay and shale.
5. Brick............	Common brick clay and shale. Terra cotta clay and shale. Drain tile clay and shale.
6. Gumbo..............	Burnt clay ballast.
7. Slip................	Clays of very easy fusibility.

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*Clays of Missouri, p. 25.

Wheeler's classification is based primarily on the use of clay. As the term implies the first group of clays is employed in the manufacture of white burning ware. The refractory clays are the fire clays used in the manufacture of fire brick, gas retorts, crucibles, saggars, muffles, etc. Pottery clays are employed in the manufacture of stoneware. Vitrifying clays are used in the manufacture of paving brick, sewer pipe, and roofing tile. Brick clays are those employed in the manufacture of brick, terra cotta and drain tile. Gumbo clays are alluvial clays employed in the manufacture of burnt ballast for road metal. Slip clays are clays of low fusibility and are used to glaze clay wares such as stoneware.

In his Economic Geology of the United States Reis gives the following form of classification based partly on mode of origin and partly on physical characters:

I. Residual clays.
    A. White burning (kaolin, formed from feldspathic rocks).
    B. Colored burning (formed from igneous, metamorphic, and many sedimentary rocks).
2. Clastic, or mechanically formed clays.
    A. Water formed (of variable extent, depending on locality and mode of deposit).
        a. White burning (ball and paper clays).
        b. Colored burning (brick and pottery clays).
    B. Glacial clays (often stony, all colored burning).
    C. Wind-formed clays (some loess).
3. Chemical precipitates (some flint clays).

The following classification of Buckley (Clays and Clay Industries of Wisconsin) is based on the origin of the deposits:

I. Residual, derived from:
    A. Granitic or gneissoid rocks.
    B. Basic igneous rocks.
    C. Limestone or dolomite.
    D. Slate or shale.
    E. Sandstone.
II. Transported by:
    A. Gravity assisted by water. Deposits near the heads and along the slopes of ravines.

B. Ice. Deposits resulting mainly from the melting of ice of the glacial epoch.

C. Water. 1. Marine. 2. Lacustrine. 3. Stream.

D. Wind. Loess.

The classification offered by Ladd (Clays of Georgia) is based on the origin and occurrence of clays. It is given below:

Indigenous.
  A. Kaolins.
    a. Superficial sheets.
    b. Pockets.
    c. Veins.
Foreign or transported.
  A. Sedimentary.
    a. Marine.
      1. Pelagic.
      2. Littoral.
    b. Lacustrine.
    c. Stream.
  B. Meta-sedimentary.
  C. Residual.
  D. Unassorted.

The indigenous clays are those formed in situ and rest upon the rock from which they were derived. The foreign group includes those which have been transported and redeposited. The marine clays were deposited in sea water, the littoral near the shore, and the pelagic in deep water. The lacustrine clays were deposited in lake basins. Stream clays are deposited on the flood plains and in the deltas of rivers. Meta-sedimentary clays are residual clays derived from once transported sediments such as the lighter pyroclastic rocks. Residual clays are those formed by the decomposition of argillaceous sedimentary rocks, such as limestones and sandstones. Unassorted clays include impure glacial clays which contain sand, gravel and bowlders and are often called bowlder clays.

Beyer and Williams use the following classification of which they say: "In the following scheme, which in the main, is the classification offered by Prof. Edward Orton of Columbus, Ohio, the subdivisions are somewhat more extensive, and while ultimate basis is that of origin, the physical and chemical properties are taken into account in making some of the lesser subdivisions."

- Primary or residual clays...............
  - Entirely decomposed feldspathic rock...Kaolin or China clay.
  - Partially decomposed feldspathic rock
    - English Cornwall-stone.
    - Porzellan Erde of the Germans.

- Secondary or transported clays.............
  - Deposited in still water
    - Fire clay...
      - Highly refractory.....
        - Flint fire clay.
        - Plastic fire clay.
      - Moderately refractory.
        - No. 2 fire clay.
        - Stoneware clay.
        - Sewer-pipe clay.
    - Indurated shales not metamorphosed
      - Slaty shales.
      - Bituminous shales.
      - Clay shales.
  - Deposited from running water....................
    - Alluvium.
    - Sandy clays.
    - Loam.
  - Deposited by glacial action.
    - Leached—Whitish or red bowlder clay.
    - Unleached—Blue bowlder clay.
  - Deposited by winds—loess.

Uses of Clay.

The uses of clay are so many and varied that it is difficult to make a short, comprehensive classification based upon that factor. However, the more important uses of clay are given in the following groups:

Brick Clays.—Common brick.—These clays may be classified according to the method of molding as soft mud, stiff mud or dry pressed; according to color, as red, salmon, mottled, etc.; according to the position in the kiln, as eye, body; according to position in the building, as front and back; according to form, as hollow, ornamental; according to treatment in burning, as vitrified, lithified, glazed, enameled and adobe (sun dried).

Vitrified brick.—Vitrified brick are made of clay shales and used for pavements and buildings. They are compact, non-porous, stony, have great crushing strength and a high degree of hardness.

Fire brick.—Fire brick are made from highly refractory clays and used in the manufacture of ovens, furnaces, as linings for fireplaces, fire boxes and stoves.

Tile clay.—Tile clay may be either common clay, shale, or fire clay used in the manufacture of drain tile, irrigating tile, roofing tile, floor tile, wall tile and fireplace tile.

Flue clay.—Flue clay is used in the manufacture of chimney flues, ventilating flues and flue brick and tile.

Stoneware clay.—Stoneware clay is used in the manufacture of jugs, churns, crocks, pitchers, jars, urns, jardiniers and sewer pipe.

Earthenware clay.—Earthenware clay is employed in the manufacture of unglazed ware, such as flower pots, filters and drain tile.

China clay.—China clay is used in the production of chinaware, porcelain, graniteware and whiteware, such as urinals, water closet bowls, basins, lavatories and sinks.

Cement clay.—Cement clay is used in the manufacture of Portland cement. When employed for this purpose the clay is mixed with a certain portion of limestone. After being pulverized it is burned to vitrification and reground to a fine flour.

Ballast clay.—Ballast clay is employed in the manufacture of a road metal for walks, wagon roads, railroads, barn floors and also for the purpose of deadening the sound in floors.

Paper clay.—Paper clay is used as a filler for printing paper, wall paper and various other papers. The clay for this purpose is utilized in the raw state.

Fuller's earth.—Fuller's earth is used to refine crude oil. Most clays used for this purpose require washing. All clay must be thoroughly dried and pulverized.

Adulterant clays.—Adulterant clays are employed in the adulteration of soap, paint and food.

Terra cotta clay.—Terra cotta clay is used in the manufacture of terra cotta brick and lumber, both plain and ornamental.

Miscellaneous clays.—Clays are also used in the manufacture of chemical apparatuses, such as evaporating dishes, pestles, mortars, ovens and crucibles. They are used for puddling in reservoirs, to temper soil, as an absorbent, for medicinal purposes, for artists' moulding material, in relief modeling in schools, in gas retorts, glass pots, smelters, saggars, electric insulating tubes, blocks, door knobs, fire kindlers, fence posts, tombstones, copings, ink bottles, emery wheels.

Occurrence of Clays.

Clays occur either in soft unconsolidated beds or as shale. Shale differs in structure from other clays. It parts readily into thin plates or irregular blocks. The direction of its cleavage is generally horizontal. In hardness it varies from that of the softest clay to that of slate, which is a product of shale metamorphism. In color shales vary, through drab, gray, black and dark blue. Weathered shales are usually yellow, red or brown. By the action of weathering the ferrous iron of the darker shales is changed to the ferric state, thus producing lighter colors. The weathered shales exhibit a higher degree of plasticity than the unweathered. They are also usually very fine grained. In chemical composition they are commonly more uniform than other clays.

CHAPTER II.

CHEMICAL PROPERTIES OF CLAY.

CHEMICAL ELEMENTS OF CLAY.

The chemical elements composing the minerals commonly present in clay are: oxygen, silicon, aluminum, iron, calcium, magnesium, sodium, potassium, titanium, hydrogen, carbon and sulphur. The last two may occur as simple elementary substances uncombined. The other elements are combined to form such compounds as lime, water and silica. In the chemical determination of these elements they are represented as combined with oxygen to form oxides.

TABLE 4.

CHEMICAL COMPONENTS OF CLAY.

Name of Component	*Chemical Symbol*
Silica	SiO_2
Alumina	Al_2O_3
Ferric oxide	Fe_2O_3
Lime	CaO
Magnesia	MgO
Potash	K_2O
Soda	Na_2O
Titanic acid	TiO_2
Sulphur trioxide	SO_3
Carbon dioxide	CO_2
Water	H_2O

Iron, lime, magnesia, potash and soda are classed as fluxing impurities. In clay the lime is usually combined with carbon dioxide (CO_2) to form calcium carbonate ($CaCO_3$), or with water and sulphur trioxide to form hydrous sulphate of lime or gypsum. Other combinations also exist so that an ultimate chemical analysis such as the above does not present, for instance, the amount of gypsum which is present in the clay, but merely the amount of water, lime and sulphur trioxide that is present in the clay. The determination of the percentage of the different mineral compounds in the clay is called its rational analysis. The rational analysis may be computed from the ultimate analysis and is useful in making clay mixtures.

The following table presents the ultimate analysis of clays belonging to each of the three classes of clays found in the State. They were selected to show the variation in the constituent elements in each group, and between each group.

TABLE 5.

ANALYSES OF SOME MISSISSIPPI CLAYS.

Kaolin.

	Per Cent			
Constituent	*No. 1*	*No. 2*	*No. 3*	*No. 4*
Moisture (H_2O)	.48	1.11	.20	1.19
Volatile matter (CO_2)	15.01	13.88	7.10	8.00
Silicon dioxide (SiO_2)	44.23	42.92	60.89	39.35
Aluminum oxide (Al_2O_3)	38.82	41.30	29.75	38.73
Iron oxide (Fe_2O_3)	.81	.61	.31	9.39
Calcium oxide (CaO)	.19	.37	.94	.34
Magnesium oxide (MgO)	.13	.13	.35	.70*
Sulphur trioxide (SO_3)	.45	.18	.39	.51
Total	100.12	100.57	99.93	98.21

Stoneware Clays.

	Per Cent			
Constituent	*No. 1*	*No. 2*	*No. 3*	*No. 4*
Moisture (H_2O)	.54	.77	.94	1.51
Volatile matter (CO_2)	7.40	6.77	6.64	8.07
Silicon dioxide (SiO_2)	59.12	62.58	67.70	61.69
Aluminum oxide (Al_2O_3)	27.44	27.58	19.69	24.91
Iron oxide (Fe_2O_3)	4.39	1.57	3.04	2.04
Calcium oxide (CaO)	.34	.40	1.06	.34
Magnesium oxide (MgO)	.28	Trace	.58	.83
Sulphur trioxide (SO_3)	Trace	Trace	.19	.20
Total	99.51	99.67	100.84	99.59

Brick Clays.

	Per Cent			
Constituent	*No. 1*	*No. 2*	*No. 3*	*No. 4*
Moisture (H_2O)	5.50	4.25	1.08	1.80
Volatile matter (CO_2etc.)	5.00	7.77	2.11	4.37
Silicon dioxide (SiO_2)	67.60	63.63	80.76	75.21
Aluminum oxide (Al_2O_3)	12.55	10.34	8.50	5.47
Iron oxide (Fe_2O_3)	7.60	8.75	4.50	5.47
Calcium oxide (CaO)	.80	3.75	1.50	.87
Sulphur trioxide (SO_3)	.17	.34	.04	.52
Total	100.00	99.33	98.94	98.88

Reis has summarized the facts to be obtained from the ultimate analysis of a clay as follows (see N. J. Geol. Survey, Vol. VI):

---

*Includes potassa and soda.

"1. The purity of the clay, showing the proportion of silica, alumina, combined water and fluxing impurities. High grade clays show a percentage of silica, alumina and water, approaching quite closely to those of kaolinite.

"2. The refractoriness of the clay, for, other things being equal, the greater the total sum of fluxing impurities, the more fusible the clay.

"3. The color to which the clay burns. This may be judged approximately, for clays with several per cent or more of ferric oxide will burn red, provided the iron is evenly and finely distributed in the clay, and there is no excess of lime. The above conditions will be affected by a reducing atmosphere in burning, or the presence of sulphur in the fire gases.

"4. The quantity of water. Clays with a large amount of chemically combined water sometimes exhibit a tendency to crack in burning, and may also show high shrinkage. If kaolinite is the only mineral present containing chemically combined water, the percentage of the latter will be approximately one-third that of the percentage of alumina, but if the clay contains much limonite or hydrous silica, the percentage of chemically combined water may be much higher.

"5. Excess of silica. A large excess of silica indicates a sandy clay. If present in the analysis of a fire clay it indicates low refractoriness.

"6. The quantity of organic matter. If this is determined separately, and it is present to the extent of several per cent, it would require slow burning if the clay was dense.

"7. The presence of several per cent of both lime (CaO) and carbon dioxide (CO_2) in the clay indicates that it is quite calcareous."

In order to determine the amount of clay substance in any of the analyses given in table 5, we may consider all the clay minerals to have the same chemical composition as kaolinite (Al_2O_3, $2SiO_2 + 2H_2O$). The average composition of some beds of kaolin is very close to the theoretical composition of kaolinite. The latter contains 39.5 per cent of alumina, 46.5 per cent of silica and 14 per cent of water. However, some beds of pure kaolin may exhibit less alumina than is contained in kaolinite. Such would be the case were the predominant mineral cimolite. On the other hand the amount of alumina present might exceed the amount in kaolinite. In this case the predominant mineral might be collyrite or a mixture of some other of the aluminum silicates with gibbsite. The amount of alumina in the first kaolin in the table above given falls a little below the amount in kaolinite. To obtain the percentage of kaolinite from the ultimate analysis multiply the quantity of alumina (38.82) by the factor 2.53 and the result obtained is 98.21 per cent instead of 100 per cent, as it would have been in the case of pure kaolinite. Now, if the amount of alumina be multiplied by the factor, 1,176, the amount of silica which enters into combination with the alumina to form kaolinite may be obtained. The amount of combined silica is found to be 45.65 per cent. But the total amount of silica is only 44.23, so that there is lacking 1.42 per cent of the silica necessary to combine with the alumina to form kaolinite. Two explanations are relevant. The kaolin may be composed largely of a mineral like collyrite, which is higher in percentage of alumina than kaolinite. Under such conditions there would be some free silica in the kaolin. The same conditions might be brought about as the result of a mixture of these two minerals, collyrite and kaolinite. On the other hand, this composition of the kaolin may be explained by assuming the presence of aluminum oxide (gibbsite) with the aluminum silicate or silicates.

Kaolin No. 2 of table 5 contains 1.8 per cent more alumina than is required for kaolinite. It also contains 7.64 per cent less silica than the amount required to satisfy the alumina. Computed as kaolinite it contains 104.48 per cent. This condition very strongly suggests the presence of gibbsite.

The amount of kaolin in the first stoneware clay of table 5 is 69.42 per cent and the amount of silica is 26.86 per cent. The decrease in the amount of clay substance in the brick clays is still more marked. The first in the table contains the highest per cent, 31.75. More than half of this clay consists of uncombined silica.

CHEMICAL COMPOUNDS OF ULTIMATE ANALYSIS.

Before taking up a discussion of the minerals commonly occurring in clays a short discussion of the chemical compounds revealed by the ultimate analysis will be given.

SILICA.

The silica, the percentages of which are expressed in the analyses of table 5, may be divided, in respect to its influence on the clay, into three parts. The first portion is that which is combined with the alumina to form the kaolin group of minerals. The second portion is combined with other silicates, such as feldspar, hornblende and mica. The third portion is uncombined silica known as free silica or sand. In making a rational analysis of a clay the last two are rarely separated. The usual method is to compute the amount of silica combined to form kaolinite. This amount called combined silica is deducted from the total amount of silica as revealed by the ultimate analysis and the remainder is called free silica. Reis has pointed out that this method is not entirely satisfactory from the clay workers' standpoint, since some of the silicates have very different properties from the quartz and may exert a very different influence on the clay ware. The effects produced upon clay by the presence of free silica are to influence its texture, its bonding power, its plasticity, its strength, its fusibility and other physical properties. These effects are discussed under physical properties of clay.

ALUMINA.

The alumina revealed by the chemical analysis is derived largely from the kaolin in the clay, but a part may be derived from feldspar and other aluminous minerals. The amount of alumina in the Mississippi clays thus far analyzed ranges from a few per cent to 41 per cent. Alumina is the most refractory substance found in clays. Besides contributing to the refractoriness of the clay it also furnishes the bonding material for holding together the inert particles. Without its presence the material could not be fashioned into the desired form.

Part of the water found in clay is in chemical union with alumina to form some hydrous silicate like kaolinite. Besides the kaolinite there are other minerals which contain water of crystallization, such, for example, as gypsum. The combined water is given up when the clay is subjected to high temperatures. Clay also contains some mechanically combined water which may be driven off at the temperature of boiling water. The amount of mechanically combined water is given in the ultimate analysis under the head of moisture.

IRON OXIDE.

The amount of iron oxide varies in different clays. It is generally least in kaolins and highest in brick clays. The chief source of iron oxide in clay is from compounds of iron, but a small amount may be derived from ferro-magnesian minerals. The iron compounds, such as hematite, limonite and siderite, may exist either in a finely divided state or as concretions in the clay. Limonite on the application of heat loses its water of crystallization and becomes red oxide of iron. It is to this last compound that the red color of clay wares is due. Siderite, the carbonate of iron, under the influence of heat gives up its carbon dioxide and becomes ferrous oxide. In the presence of oxygen the ferrous iron may be changed to the ferric oxide, the red oxide.

The sulphide of iron may also be reduced to the ferric oxide under the action of heat. Iron is also a fluxing ingredient of clays. When the iron compound is reduced to the ferrous state in the absence of oxygen it will unite with silica forming a ferrous silicate. In the presence of other easily reducible compounds the ferrous silicate may act as a rapid solvent. If there is plenty of oxygen present the ferrous oxide will be further oxidized to the more refractory ferric state.

CALCIUM OXIDE (LIME).

The amount of lime in clays is generally below five per cent. Some brick clays, however, contain as much as twenty per cent. The origin of the lime is from limestone (calcium carbonate) and gypsum (calcium sulphate). Small amounts of lime may be derived from lime-bearing silicates, some of which are of common occurrence in clays. The effect produced by the presence of lime in clay will depend on the distribution of the lime and the amount present. Lime concretions may produce cracks in bricks by absorbing water and slaking after the brick are burned. In the presence of iron these concretions may fuse and cause cavities or slaggy masses in the brick. The same amount of lime finely divided and uniformly distributed through the clay would have no detrimental effect. However, since lime acts as a flux, its presence in appreciable quantities tends to lower the fusion point of the clay. For this reason vitrifying clays should not contain much lime. In the presence of a considerable quantity of iron the fluxing action of lime may be rapid and effective. With only a small increase of temperature above incipient fusion the brick may be reduced to a slaggy mass. Lime in considerable quantities in a common brick clay may also prevent the development of a red color in the ware.

MAGNESIA.

The source of magnesia in clay is from magnesium carbonate, from magnesium sulphate, and more rarely from silicates containing magnesium. Dolomite or magnesium limestone is the chief source. This mineral is a calcium-magnesium carbonate ($\frac{1}{2}$ Ca, $\frac{1}{2}$ Mg, CO_3). By the decomposition of pyrite in clays sulphuric acid may be formed. The latter may attack the magnesium carbonate and form magnesium sulphate. The sulphate is soluble in water and if the drainage of the clay bed is perfect it will cause the sulphate to be carried out by circulating waters. If the sulphate is not separated from the clay it will be brought to the surface of the ware either in drying or burning and produce efflorescence. The action of magnesia under heat is said to correspond to that of lime with the exception that at high temperatures the magnesia is not as rapid a fluxing agent as lime.

ALKALIES.

The alkalies commonly found in clays are potash (K_2O) and soda (Na_2O). The per cent of alkalies contained in the clays of Mississippi so far determined is small. Alkalies in clays are commonly derived from silicate mineral, such as feldspar. The compounds of potassium and sodium formed by the breaking down of these complex compounds are sulphates, carbonates and chlorides. These compounds being soluble are removed from the clay under perfect drainage conditions. Imperfectly drained clay beds may contain a considerable amount of these compounds. The alkalies act as powerful fluxes. They fuse at a low temperature, the soluble salts at about red heat. The silicates fuse at higher temperatures. The soda silicates fuse at lower temperatures than the potash silicates The feldspars are considered an aid to vitrification since they produce a longer period between incipient fusion and complete vitrification They are detrimental to high degree of refractoriness

MINERALS IN CLAYS.

The minerals composing clays may be classed as essential and non-essential. The determination of essential components will be controlled by the use for which the clay is intended. Iron, for example, is an essential element in any clay intended to be red-burning. On the other hand it is non-essential and detrimental to a clay intended to be white-burning.

The minerals most commonly found in clays are silica, feldspar, mica, iron compounds, such as hematite, limonite, magnetite, siderite and pyrite, kaolinite, calcite, gypsum and hornblende. Others occurring somewhat less commonly are rutile, glauconite, dolomite, garnet and fluorite. Pure clay is a mixture of kaolinite, meershaluminite, halloysite, newtonite, cimolite, pyrophyllite, allophane, collyrite, montmorillonite and schrötterite, silicates of aluminium and gibbsite, an oxide of aluminium. Rock formed of one or more of these minerals is called kaolin. All the other minerals found in clay are termed impurities. The clay compounds and the impurities result from the decay of rocks. For example, granite composed, say, of feldspar, mica and quartz, may, by decomposition, form allophane, cimolite, kaolinite, biotite, quartz, magnetite, damourite, epidote, gibbsite, muscovite, chlorite, diaspore, limonite, pyrophyllite, newtonite, hematite and hypersthene. Further alteration may result in the formation of other compounds. In the following pages a discussion of the properties of some of the minerals commonly found in clays are given.

KAOLINITE.

Kaolinite (Al_2O_3, $2SiO_2$, $2H_2O$) is an hydrous silicate of aluminum containing 46.5 parts of silicate; 39.5 parts of alumina and 14 parts of water. It is a compact friable or mealy mineral having a greasy feel. It is composed of microscopic scales or crystals which in the aggregate are white in color. It is a soft mineral having a specific gravity of 2.63. Kaolinite results from the decomposition of aluminous minerals, especially the feldspars, one of the common and essential constituents of granites and gneisses. It is found in the rocks of all ages from the Archean to the Recent. Some of the varieties of kaolinite contain more alumina and less water than that in the formula given above. Beds of kaolinite and associate minerals are called kaolin.

In the decomposition of feldspar to form kaolin, the potash and other bases are removed by the action of meteoric waters containing carbon dioxide. The residual aluminium silicate takes up water, forming an hydrous aluminium silicate or oxide. The aluminous minerals found in kaolin are here given:

TABLE 6.

ALUMINOUS MINERALS FOUND IN KAOLIN.

	Silica	*Alumina*	*Water*
Kaolinite, H_4Al_2 (Si_2O_9)	46.05	39.5	14.0
Meerschaluminite, $2HAl$ (SiO_4) + aq	43.15	41.07	15.78
Halloysite, $H_4Al_2(Si_2O_9)$ + aq	43.5	36.9	19.6
Newtonite, $H_8Al_2(Si_2O_{11})$ + aq	38.5	32.7	28.8
Cimolite, $H_6Al_4(SiO_3)_9$ + aq	63.4	23.9	12.7
Pyrophyllite, $H_2Al_2(SiO_3)_4$	66.7	28.3	5.0
Allophane, $Al_2(SiO_5)5H_2O$	23.8	40.5	35.7
Collyrite, $Al_4(SiO_8)9H_2O$	14.1	47.8	38.0
Schrötterite, $Al_4(SiO_8)30H_2O$	11.7	53.1	35.2
Gibbsite, $Al_2O_33H_2O$	......	65.4	34.6

SILICA.

Silica (SiO_2) is usually the most abundant mineral in clays. The composition of silica is silicon, 46.7 parts and oxygen, 53.3 parts. It exists in clay either free or combined. Combined with other substances it forms silicates. The amount of free silica or quartz sand occurring in clay varies from 1 to 50 per cent. The total amount of silica may be much higher, often as much as 70 or 80 per cent. In such clays the percentage of free silica is very high.

The size of the quartz grains in clays is extremely variable. They range from those particles large enough to be removed by screening to those of exceedingly small microscopic size. The grains are transparent, of milky translucence or stained by iron compounds. Quartz grains which have not been transported are usually angular in form. The transported grains have become rounded by the abrasion incurred during transportation. Since quartz is a very hard mineral, being seventh in the scale of hardness, it is not easily broken up, and because of its insolubility it is not easily decomposed. For these reasons it forms a considerable portion of many sedimentary rocks, and especially of the mantle rock.

Quartz alone is nearly infusible, being fused at cone 35 of the Seger series, a temperature of about 3,326° F. Although of such high refractoriness it may or may not add to the refractoriness of a clay. Under certain conditions, as when the amount of fluxing materials is high, an addition of quartz may raise the fusion point, but such fusion point will be much lower than the fusion point of pure quartz. Quartz added to clay having a low per cent of fluxing impurities may tend to lower the fusion point of the clay.

The addition of quartz to clay will reduce the shrinkage of the clay. It will also decrease the plasticity but the amount of reduction will depend on the size of the quartz grains. Clays containing a high percentage of quartz of coarse grain slake more readily than other clays. Clays containing a high percentage of very finely divided quartz slake slowly and are very sticky clays. Quartz of coarse grain adds to the porosity and absorption power of a clay.

IRON.

The element iron may occur in clays in a number of forms. It may be present as a sulphide, an oxide, a carbonate, an hydroxide, a sulphate or a silicate. In the manufacture of some clay wares a limited amount of iron is desirable. For instance in red ware such as brick and tiling the color is dependent on the oxidation of the iron compounds in the clay. A very low per cent of iron is desirable in a clay to be used in the manufacture of white ware of any kind. Some clays burn white notwithstanding the presence of a large per cent of iron; especially is this true when a considerable portion of carbonate of lime is present. The iron compounds commonly found in clays are limonite, hematite, siderite and pyrite.

Limonite.—Limonite is an hydroxide of iron ($2Fe_2O_3$, $3H_2O$). It contains 59.8 per cent of iron, 25.7 per cent of oxygen, and 14.5 per cent of water. As an ore it may occur in rather compact crystalline masses or as grains mixed with clay, in which form it is called yellow ochre. The yellow or brown color of many clays is caused by the presence of appreciable amounts of limonite. Limonite may occur in clays as a coating for the sand grains, as distributed through the clay in very fine particles, and as large lenticular concretions. It occurs as bog ore in ponds and marshes, having been brought into the water in a soluble form as a sulphate or carbonate or as some organic salt through the action of some organic acid. It is precipitated by oxidation and its presence is revealed by an iridescent oil-like film upon the surface of the water. Limonite may result from the alteration of other ores, through the action of atmospheric agents and the presence of organic acids. Through alteration processes it is derived largely from pyrite, magnetite, siderite and from silicates containing iron in the ferrous state. Under the action of carbon dioxide it may be changed to siderite. By hydration it may be changed to hematite. It forms the cementing substance for many sandstones and conglomerates. Under the influence of heat limonite loses its water of crystallization and is changed to the red oxide.

Hematite.—The red oxide of iron (Fe_2O_3) is also a common constituent of clays. This compound contains 70 per cent of iron, and 35 per cent of oxygen. It is found widely distributed through the rocks of the earth's crust. It occurs in the form of tabular or rhombohedral crystals known as specular iron. In hexagonal plates it is known as micaceous hematite. In minute particles it is found as a coating for sand grains and is also disseminated through clays and other rocks of this form. It sometimes occurs in clays in concretionary masses. These masses may be coated with limonite which is the beginning of the process of alteration. In beds of soft rock it forms red ochre. The occurrence of hematite may be due to the alteration of some other iron compound. For instance pyrite by oxidation may be changed to hematite. Magnetite and siderite may also be altered to hematite. Silicates such as hornblende, for example, may be decomposed, producing hematite as one product. Hematite may be altered to magnetite and then changed to siderite by the action of carbon dioxide. When acted on by sulphuretted hydrogen it may form pyrite, or by taking up water it may become limonite.

Siderite.—The carbonate of iron ($FeCO_3$) may occur in clays as minute particles somewhat uniformly distributed and as concretionary masses. Siderite contains 62.1 per cent of iron protoxide and 37.9 per cent of carbon dioxide. It is found in many sedimentary and metamorphic rocks. In shales and clays it frequently occurs as iron stones, especially in beds associated with coal deposits. There are several varieties based on composition. Some of these contain magnesium, others manganese, and still others calcium. There are also several varieties as to form. It may be crystalline, earthy, concretionary, granular, compact or oölitic.

Where uniformly distributed through clay it may give it a slate color. By oxidation siderite may be altered to hematite, to limonite or to magnetite. When present in considerable quantities in a clay it may act as a flux, causing the clay to be fused at a lower temperature. When heated it loses its carbon dioxide and becomes ferrous iron (FeO). The FeO may unite with silica and form a ferrous silicate, FeO_2, $2SiO_2$, which gives to the ware a dark green color.

Pyrite.—Iron pyrites or fool's gold is a bright brassy mineral of common occurrence in clays and shales. Its chemical symbol is FeS_2, and its composition is iron 46.6 per cent and sulphur 53.4 per cent. Its common occurrence in clay is in the form of crystals or concretionary nodules of various shapes. Many of these are radiate in structure. In the presence of air and moisture the pyrite (FeS_2) alters to iron sulphate, iron oxide and sulphur. If lime carbonate is present the iron may be changed to the hydroxide and the sulphur trioxide uniting with the calcium may form gypsum ($CaSO_4$, $7H_2O$). Thus by the action of weathering pyrite may be removed from clay. Pyrite may be changed to limonite by oxidation and hydration. By dehydration the limonite may be altered to hematite.

When FeS_2 is subjected to heat the Fe becomes oxidized to FeO and the sulphur is converted into SO_2 or SO_3. At low temperatures FeS_2 loses S and becomes FeS. At still higher temperatures FeS is changed to FeO and SO_2. In the presence of oxygen the SO_2 may be converted into SO_3.

Marcasite.—Marcasite is a variety of iron disulphide having the same chemical composition as pyrite. It is a common impurity in lignitic clays. Its color is pale bronze-yellow. In clays it frequently occurs in nodules of radiating crystals called "sulphur balls." Atmospheric alteration of marcasite takes place very rapidly. For this reason weathering the clay is one of the most effective means of removing the impurity.

Ilmenite.—The mineral ilmenite, or menaccanite, is an oxide of iron and titanium ($TiFeO_3$ or $(TiFe)_2O_3$). It is an opaque mineral of black or brownish-black color. The normal variety contains 31.6 per cent of titanium, 36.8 per cent of iron, and 31.6 per cent of oxygen. Since this mineral is very refractory and not easily acted on by the agents of decomposition, it is a common constituent of many residual and transported deposits. It also occurs as an original constituent of many igneous rocks. It is sometimes found in tabular crystals, plate like masses or in grains in veins of metamorphic rocks. In many sedimentary rocks it is present in small rounded grains. There are a number of varieties of the mineral distinguished by varying proportions of iron and titanium. In some species the iron is partly replaced by magnesium. Ilmenite may be altered to leucoxene or titanite.

GYPSUM.

Gypsum ($CaSO_4 2H_2O$) is a hydrous sulphate of calcium. It is composed of 32.6 parts of lime, and 20.9 parts of water, and 46.5 parts of sulphur trioxide. Gypsum occurs as individual crystals, as crystalline aggregates, as crystalline sands, or in massive beds of earthy material. It may be precipitated from sea water under conditions similar to the deposition of common salt. It may also result from the decomposition of pyrite in the presence of lime carbonate. The reactions involved are as follows:

$FeS_2 + 6O = FeSO_4 + SO_2$ or
$FeS_2 + 3O + H_2O = FeSO_4 + H_2S$.
Then $FeSO_4 + 2O + 7H_2O = 2Fe_2O_3\ :3H_2O + 4H_2SO_4$.
In the presence of lime
$CaCO_3 + FeSO_4 = CaSO_4 + 2H_2O + FeCO_3$ or
$H_2SO_4 + CaCO_3 = CaSO_4 + H_2O + CO_2$.

There are several varieties of gypsum, the clear, transparent, crystalline kind is called selenite. Satin spar is a fibrous variety with a satin-like lustre. Alabaster is a white, fine-grained variety used in making ornaments. Gypsite is an earthy variety occurring in thick beds of varying purity. Selenite and gypsite both occur in some of the clays of Mississippi. Aggregates of selenite crystals are of common occurrence in the clays of the Jackson group. By the decomposition of pyrite in the Selma chalk the residual clays of that formation contain sufficient gypsum in some localities to cause efflorescence on brick manufactured from the clay. A discussion of the effects of gypsum may be found under lime and efflorescence.

CALCITE.

The mineral calcite ($CaCO_3$) is composed of 56 parts of lime (CaO) and 44 parts of carbon dioxide (CO_2). Calcite is the chief constituent of limestone, chalk and marble. It occurs also in marls, shales and sandstones in small grains or crystals. Its presence in sedimentary rocks is largely due to the accumulation of organic remains, and possibly to a less extent to precipitation from aqueous solutions. There are several varieties of calcite. Iceland spar is a clear transparent variety having the power of double refraction. Dog-tooth spar occurs in crystals, the form of which suggests the name. Aragonite has the same chemical composition as calcite but differs in its crystallization. Marble, or crystalline limestone, is composed largely of calcite. Tufa, travertine and argentite are composed principally of calcium carbonate.

When calcite is heated to a temperature of 1,296° F the CO_2 in composition is driven off and lime (CaO) remains. On the addition of water the calcium oxide (CaO) will be changed to calcium hydroxide ($Ca(OH)_2$) with the evolution of heat.

Nearly all clays contain at least small quantities of calcite. The presence of calcite tends to lower the fusion point of the clay. Where present in large quantities or where unevenly distributed it may produce cracking or breaking of the brick due to the evolution of gas and of heat in slaking. Unless the brick are porous it is possible for the outside of the brick to vitrify before all of the gas has been expelled from the inside. This causes a swelling or puffing of the brick.

Many residual clay deposits have been formed by the decomposition of limestone containing clay. The lime carbonate is dissolved by acidulated meteoric waters and carried away, while the insoluble clay is left as a residual product. The amount of clay in the limestone may be exceedingly small, yet in time and under the proper conditions a bed of clay of considerable thickness may accumulate. Such residual clays have been formed in Mississippi by the dissolution of the Selma chalk and the Vicksburg limestone. Beds of clay so formed usually rest directly upon the surface of the limestone and often contain, especially in the lower portions, nodules of lime carbonate which represent the more insoluble parts of the limestone. These are often a source of annoyance to the brick maker. They interfere with the cutter and cause flaws in burning

If the bottom clay is used it ought to be crushed so as to distribute the lime through the clay, in which condition it is harmless.

FELDSPAR.

The feldspars are silicates of aluminum containing calcium potassium, sodium or barium. There are nine principal varieties which are divided crystallographically into two groups: first, the monoclinic feldspars, orthoclase and hyalophane; second, the triclinic feldspars, microcline, anorthoclase, albite, oligioclase, andesine, labradorite and anorthite. The chemical constituents of each of these feldspars is given in the following table from Dana's Mineralogy:

TABLE 7.

CHEMICAL COMPOSITION OF FELDSPARS (DANA).

	Silica	*Alumina*	*Potash*	*Soda*	*Lime*	*Barium*
Species	SiO_2	Al_2O_3	K_2O	Na_2O	CaO	Ba
Orthoclase	64.7	18.4	16.9	....	....	....
Hyalophane	52.0	22.0	7.0	3.0	1.0	15.0
Microcline	65.0	18.0	17.0	....	....	....
Anorthoclase	66.0	20.0	4.0	7.0	1.0	....
Albite	68.0	20.0	....	12.0	12.0	....
Oligioclase	62.0	24.0	....	9.0	5.0	....
Andesine	57.0	27.0	....	9.0	7.0	....
Labradorite	53.0	30.0	....	4.0	13.0	....
Anorthite	43.0	37.0	....	....	20.0	....

Feldspar is found in crystals in igneous and metamorphic rocks and as grains in some fragmental rocks. It is one of the essential constituents of granite. By the action of carbonate waters on lime and other bases of feldspar they may be taken into solution and the feldspars decomposed. The decomposition of the feldspar results in the formation of new compounds. These new compounds are aluminous silicates like kaolinite. The decomposition of pyrite may produce sulphuric acid which will aid in the decomposition of feldspar. The decomposition of feldspathic rocks is the original source of clay.

Feldspar is commonly associated with quartz in sand and is for that reason a constituent of most clays. Like quartz it serves to decrease shrinkage in clays, but since it fuses at a much lower temperature (2,192° F) it may form a chemical union with other substances and act as a flux.

MICA.

Mica is a polysilicate composed of iron, aluminum, calcium, magnesium, manganese and silica. The mica group of minerals contains more than a half dozen important varieties. They are all silicates of aluminum but vary in other constituents, viz.: potassium, lithium, magnesium and iron. There are two common varieties. The first is a white variety called muscovite. It has the following composition: silica, 45.2 per cent; alumina, 38.5 per cent; potash, 11.8 per cent, and water, 4.5 per cent. The second is a black or dark variety, called biotite $(Mg, Fe)_2\ Al_2Si_3O_{12})$, the potassium of the former being partly replaced by magnesium and iron. One of the most notable physical characters of mica is its perfect cleavage in one direction permitting it to be separated into very thin plates. It has a low degree of hardness.

Mica is an essential constituent of many igneous and metamorphic rocks. When granite and other mica-bearing rocks are decomposed the crystals of mica are broken up into small thin flakes. These flakes are found in residual clays, and on account of the low specific gravity of the particles, are transported long distances and occur in most transported deposits.

Under the action of weathering mica may lose its potash and take up water and soda, manganese or lime. In brick clays the mica grains may be little affected by a temperature sufficiently high to produce a serviceable brick, and the bright unchanged particles are sometimes seen upon the surface of a fresh fracture. At high temperatures the mica may be fused and it is therefore detrimental to fire clays if present in sufficient amount. Because of the presence of iron it is detrimental to white ware burned at high temperatures.

HORNBLENDE.

Hornblende is a silicate belonging to the amphibole group of bisilicates. In contains 48.8 parts of silica; 18.8 parts of iron; 13.6 parts of magnesia; 10.2 parts of lime and 1.1 part of manganese. It may occur in crystals, fibers or in a massive form. It is an essential constituent of diorite, and also occurs in other rocks. There are many varieties of hornblende. Actinolite, asbestus, nephrite and tremolite are light colored varieties. Pargasite, beramaskite and black hornblende are varieties of the dark colored amphiboles. There is a great variety of colors. The predominant colors are black, white, green and brown. Hornblende is hard and has a vitreous or silky lustre. The residual product of the decomposition of hornblende is a clay which contains a high per cent of iron. The iron compounds which may be formed by its decomposition are limonite, magnetite and hematite.

CHAPTER III.

PHYSICAL PROPERTIES OF CLAY.

The physical properties of clay which, from the clay-workers' standpoint, are most valuable, are plasticity, strength and refractoriness. Plasticity enables the worker to fashion the clay into the desired form. The strength of the clay permits the clay ware to be handled during the drying and burning processes without danger of breakage. The power of the clay to withstand high temperatures permits it to be burned to a compact, hard body of permanent form. While these are, for the majority of wares, the most important physical properties there are other properties of very great importance in the manufacture of some wares. In our investigation of the clays included in this report, we have considered the following properties:

Structure.
Shrinkage.
Specific gravity.
Color.
Hardness.
Feel.
Odor.
Taste.
Slaking.
Plasticity.
Fusibility.
Fineness of grain.
Bonding power.
Tensile strength.
Porosity.

STRUCTURE.

The structure of a clay refers to its mode of occurrence in the outcrop or pit. A stratified clay is one which occurs in layers. A massive clay is one in which no division planes are seen. A clay which splits readily in thin leaves or irregular blocks is said to be shaly. If the leaves are small, thin and light the term chaffy is applied to it. A slaty clay is one in which the laminae have undergone a considerable degree of induration. Instead of occurring in layers some clays are found in concretionary or pebbley masses. Joint clays are those which are separated into blocks by vertical crevices. This structure is an aid to the mining of many clays. These various structures in clay are the result of deposition, compression, and induration. In the process of weathering they are obliterated, and the rapidity of such weathering action is often dependent on the structure of the clay. The speed with which a mineral producing soluble salts can be removed by weathering will depend upon the structure of the clay. In order that clay may be used in the formation of clay wares, it must be reduced to a structureless mass. For this purpose it is necessary to employ disintegrating or pulverizing machinery. The expense of this process will be determined by the degree of induration which has taken place in the clay structure.

SHRINKAGE.

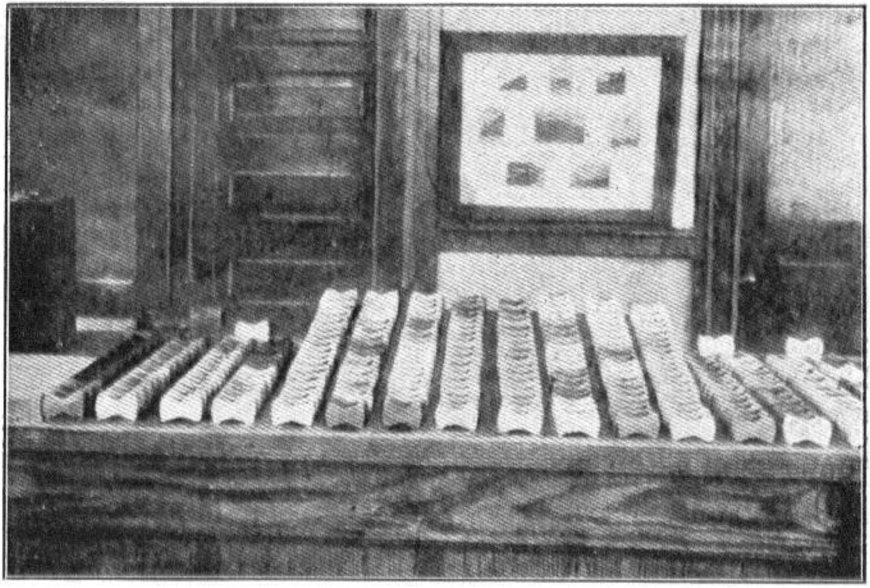
The amount which a clay contracts in passing from a plastic condition to that of a rigid solid is termed its shrinkage. The water which is added to the clay in order to render it plastic is lost by evaporation, causing a loss of volume. The loss of volume or shrinkage varies greatly in different clays and with different conditions of the same clay. Water added in excess of the amount required for plasticity will cause a greater loss of volume, as will also the presence of air bodies in the clay. Considerable water may exist in the clay without increasing the volume, but whenever the particles of clay are completely enveloped in water, the volume and the plasticity will be increased. Water absorbed by a clay exists either interstitial, *i. e.*, in the pores, or interparticle, *i. e.*, not occupying the pores but causing a separation of the particles. It is the latter which increases the volume of a clay. Clays of coarse grain have large interstices and contain large quantities of interstitial water, but less interparticle water than clays of finer grain; therefore, the fine grain clay shrinks more than the coarse grain.

AIR SHRINKAGE.

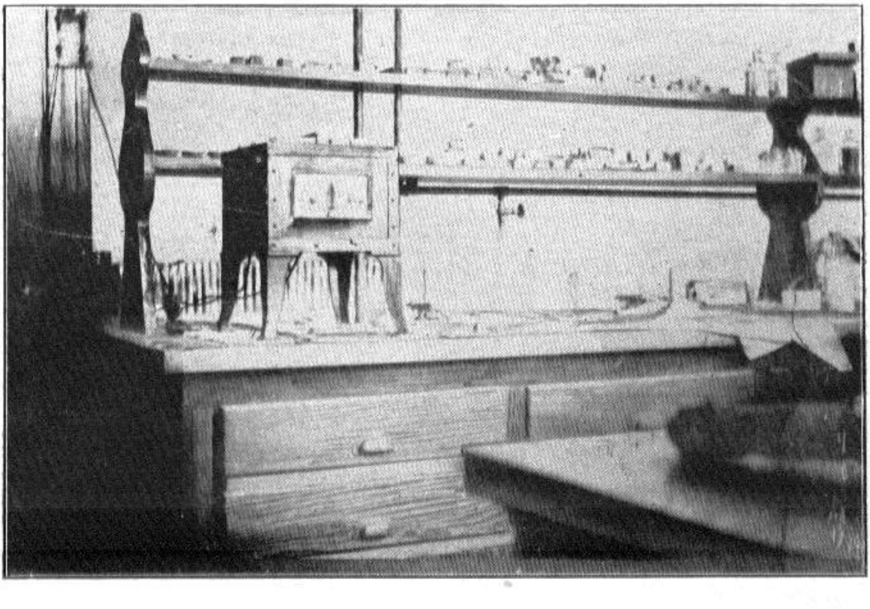
The amount of contraction which a clay undergoes when drying in the air is called its air shrinkage. The amount of air shrinkage depends mainly on two factors; first, the amount of water absorbed; second, the size of the grain.

A number of methods of preventing excessive shrinkage is employed. The method more generally in use is that of mixing a sandy clay with the more plastic clay. Under ordinary conditions this is the most economical method. In the greater part of the surface clay deposits of this State the upper portion of the clay bed contains available sandy clay. The plastic, residual clays are sometimes diluted with the underlying non-plastic loess. Pure sand and crushed brick are sometimes used to decrease shrinkage and produce

PLATE III.



A. BRICKETTES FOR TENSILE STRENGTH TEST.



B. ELECTRIC FURNACE FOR TESTING CLAYS.

more rapid drying. Crushed coal cinders are successfully employed in some plants. Chopped straw, sawdust, lignite and coal dust may also be employed. The effects produced by the use of non-plastic materials is to decrease its plasticity and its bonding power. On the other hand, they may cause the clay to mold without lamination, increase the speed of drying and burning, and prevent cracking and checking. The use of combustible substances leaves the brick more porous than the mineral substances. From a fuel standpoint their use is economical, since the clay particles are brought in immediate contact with the clay. The danger of swollen ware will be referred to under the subject of "Causes of Swollen Brick." Unless a large amount of oxygen is supplied to the kiln in the draft the organic matter in the clay may rob the iron compounds of their oxygen and cause a pale yellow color in red burning clays. The use of cinders is free from some of these objections. They decrease shrinkage, plasticity, bonding power, and tensile strength in the raw clay. They cause the clay to dry more rapidly and to burn in less time. They do not increase the porosity of the clay as do the combustible substances and the tensile strength of the burned clay is not diminished as much. The table below shows the effect of coal and cinder dilution on the tensile strength of raw and burned clays.

TABLE 8.

EFFECT OF COAL AND CINDER DILUTION ON THE TENSILE STRENGTH OF RAW AND BURNED CLAYS.

	Tensile strength in pounds per square inch.	
Locality	*Raw clay*	*Burned clay*
Starkville brick clay	133	146
Starkville brick clay and 10% coal	119	150
Starkville brick clay and 10% cinders	75	153
Amory brick clay	100	220
Amory brick clay and 10% coal	140	263
Amory brick clay and 10% cinders	175	300
Morton clay	81	131
Morton clay and 10% coal	130	192
Morton clay and 10% cinders	100	235
Wahalak clay	112	170
Wahalak clay and 10% coal	77	222
Wahalak clay and 10% cinders	74	150

The first clay is residual Selma, the second is Tombigbee second bottom, the third is a residual Jackson and the fourth belongs to the Porter's Creek (Flatwoods) formation. These clays are all highly plastic and the shrinkage is excessive. The non-plastic material was added to decrease shrinkage and to increase the speed of drying and burning. All of these objects were attained, and, as the experiments seem to prove, not greatly at the expense of the strength of the ware when the ware is compared with that of the original clay. The brickettes were given a medium burn.

FIRE SHRINKAGE.

The loss of volume which the clay sustains in passing from the raw to the burned condition is termed its fire shrinkage. The loss of the chemically combined water in clay and the combination of the organic matter causes an increase in the porosity of the clay. When the temperature is carried to the point of vitrification the pore space and the natural pores are closed. A loss of volume results. Sandy clays not burned to vitrification may not exhibit any fire shrinkage. Some clays containing a high per cent of organic matter when subjected to a rapidly increasing temperature may become viscous on the outside, thus preventing the escape of hydrocarbons formed from the distillation of the organic matter and causing the brick to slightly increase in volume.

The following table shows the air shrinkage and the fire shrinkage of some Mississippi brick clays burned at a good red heat and forming a medium burn.

TABLE 9.

SHRINKAGE IN MISSISSIPPI CLAYS.

Formation	*Locality*	*Air Shrinkage*	*Fire Shrinkage*
Brown loam (middle)	Vicksburg	3½%	0 %
" "	Lexington	3⅓%	0 %
" " (bottom)	Sardis	6⅗%	2 %
" "	Holly Springs	3⅓%	1 %
Yazoo alluvium (buckshot)	Indianola	10 %	2 %
" " "	Moorhead	15 %	3 %
" " "	Greenville	10 %	2½%
" " (sandy)	Elizabeth	5 %	1 %
" " "	Clarksdale	4 %	2⅘%
" " "	Minter City	5 %	1 %
Porter's Creek (Flatwoods)	Macon	10 %	2 %
" " "	Wahalak	10 %	2 %
" " "	Starkville	10 %	1 %
Lafayette	Canton	8 %	0 %
"	Hernando	5 %	1 %
Jackson	Canton	10 %	1 %
"	Morton	10 %	1 %
"	Barnett	10 %	2 %
Buhrstone	Vaiden	10 %	0 %
Selma residual	Starkville	5 %	1 %
" "	West Point	4 %	0 %
" "	Booneville	5 %	1 %
" "	Verona	5 %	1 %

SPECIFIC GRAVITY.

The specific gravity of a rock is its weight compared with the weight of an equal volume of distilled water at 60°F. The specific gravity of a substance is obtained by weighing it in air and by weighing it in water and then dividing its weight in air by its loss of weight in water. The specific gravity of clays usually varies from 1.50 to 2.50, but there are some clays whose specific gravity is lower and others whose specific gravity is higher than these limits. Pure kaolin has a specific gravity of from 2.4 to 2.6. Pure quartz sand has a specific gravity of from 2.5 to 2.8. Where clay is largely a mixture of varying proportions of these two minerals, its specific gravity is not far from 2.5. Clays containing in addition to these minerals mica and limonite are slightly heavier. The presence of magnetite, however, may greatly increase the specific gravity, while on the other hand organic matter may decrease it.

Methods of determining specific gravity are not uniform and different methods may produce different results in the same clay. By the use of the pycnometer the specific gravity of the individual grains is determined and taken as the specific gravity of the clay. By another method the specific gravity of lumps of clay which have been coated with paraffin is determined. This method considers the pore space a part of the clay. The specific gravity of any clay is less by the latter method.

COLOR.

The color of clays is an exceedingly variable property. Many shades and tints are represented. The color may be due either to the presence of organic matter or to the presence of iron and manganese compound. Shades of red, buff or brown are generally due to the presence of iron oxides. Blue and dark colors are sometimes caused by the presence of iron carbonate or of organic matter. White clays are devoid of susceptible coloring matter, but some white clays have color developed by burning.

By the color of the raw clay it is not possible to predict the color of the burned product unless the nature of the coloring matter and its amount are known. Some white clays contain enough iron to produce a dark shade when burned in an oxidizing flame. Titanium may produce a purple tint when the clay is burned at a high temperature. Some black clays are found to be very white after burning. The dark coloring matter in many clays is organic matter which is burned out, leaving the product white. Some yellow or red clays containing an excess of iron may burn to an iron black.

The color to which a clay will burn often has an important bearing on its value. A clay which may be of high value as a stoneware clay, for instance, may be entirely useless as a whiteware clay, because of the presence of coloring matter which would develop dark shades or splotches during burning. Even in common brick clays the color is of importance. The nearly colorless Milwaukee brick clay is of greater commercial value than the more common red or yellow burning clays. The most satisfactory test to determine the color of the burned product is to subject a sample of the clay to the same conditions of temperature to which the proposed ware is to be subjected. The shades of the burned clay are almost as variable as the natural clay.

The oxidation of iron compounds in the clay produces light reds, cherry reds, dark reds, chocolates and iron blacks, the latter being produced by an excessive amount of iron. Clays may contain a considerable quantity of iron and still be white or yellow. Vitrified wares contain iron silicates which may give a green, brown or black color. Spots on white, yellow or red wares are produced by sprinkling the surface of the clay product with iron or manganese particles. The oxidation or reduction of these particles produce black, brown or red specks on the wares.

HARDNESS.

The property by virtue of which one mineral is able to scratch another mineral is called hardness. Clays are soft rocks. They usually range in the scale of hardness from one to three. The maximum degree of hardness is represented in the flint clays while the minimum degree is attained in the chalk-like kaolin. This property refers to the ease with which the rock may be scratched. The individual particles in a clay may be a great deal harder than the rock. For instance, the quartz would have a hardness of seven, while the feldspar would have a hardness of six. Kaolinite has a hardness varying from 1 to 2.5.

Burnt clay has a much higher degree of hardness than raw clay. Vitrified clay products reach a hardness equal to that of quartz, which will readily scratch glass. Hardness is a property very essential in all clay wares which are to be subjected to abrasion, as are paving brick; or to compression, as are building brick; or to chemical action, as are sewer pipe.

FEEL.

Clay containing particles of sand are harsh or gritty to the touch. The grit in some clays may be detected by rubbing the clay between the fingers. In other clays the grit can only be detected by moistening the clay between the teeth. Clays having a large percentage of clay base are smooth to the touch. Kaolin is somewhat like talc or soapstone to the touch. It is a very common practice for people to refer to an unctuous clay or shale as a soapstone. These clays may be shaved with a knife to a perfectly smooth surface, while a clay containing grit will have minute pits upon its surface where the blade of the knife has pulled out the sand grains. The moistened surface of the unctuous clay feels greasy or soapy. As a general rule the gritty clays are the least plastic and are called "lean" or "short" clays, while the more unctuous clays are the more plastic and are called "fat" clays.

ODOR.

The odor which emanates from the moistened surface of clay is distinct and characteristic. A very similar odor is given by the surface of some minerals when they are rubbed, and they are said to have an argillaceous odor. Some clays containing decaying organic matter have a fetid odor. Some very silicicus clays contain such a small amount of clay substance that the argillaceous odor is not distinct. Some clays containing a very high per cent of clay substance do not give off an argillaceous odor. Therefore, this property cannot be counted a safe guide to the amount of clay substance.

TASTE.

The presence of certain soluble salts in clay may be detected by tasting the clay. Common salt, alum and ferrous sulphate are not infreqeuntly detected in this way. Clay prospectors sometimes place clay between the teeth in order to determine its proportion of sandy matter. They also employ this method to determine the texture and degree of plasticity.

SLAKING.

The crumbling of a clay under the action of water is termed slaking. When a clay slakes it breaks up into small fragments.

Slaking takes place wherever an air-dried clay surface is exposed to the action of water. The size of clay fragments or grains into which the clay mass is separated is fairly uniform for the same clay, but varies greatly in different clays. The shape of the particles is variable. Some are flat, some cubical, others irregular. As the particles of the clay separate they absorb water and increase in size.

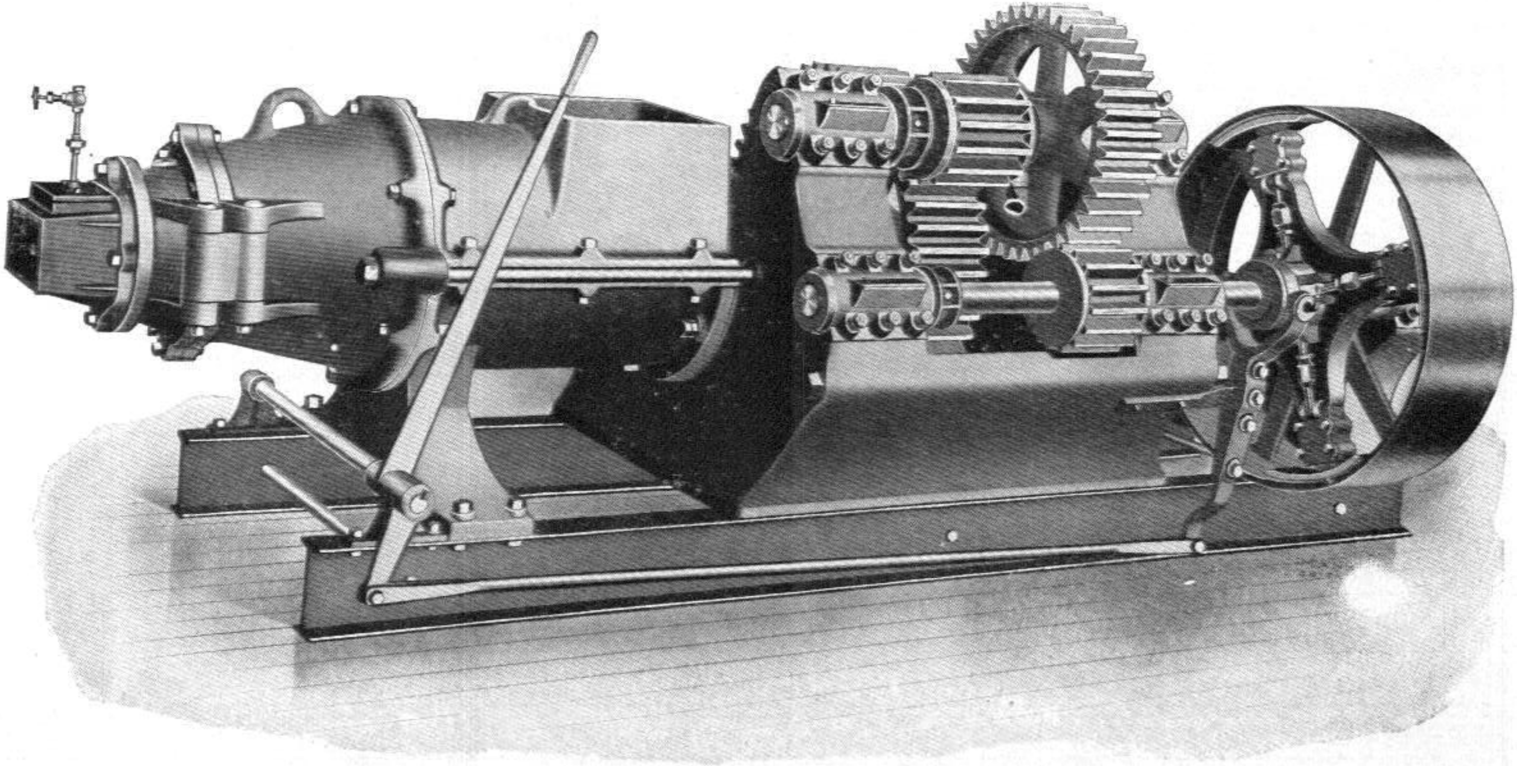
The speed of slaking varies in different clays. Clays of marked density, such as shale and flint clays, slake very slowly while the leaner surface clays slake very rapidly. Wet or puddled clays do not slake as rapidly as air-dried clay to which water is suddenly applied. The speed of slaking is determined by taking samples of natural clays of equal size and placing them in water and by observing the time elapsing until they are completely crumbled. A cube one inch in diameter of a lean loess clay from Grenada, Grenada County, was completely separated in less than ten minutes, while a shale from Mingo, Tishomingo County, was little affected after remaining in water one week.

Clays having a high slaking speed are usually very lean or sandy. The loess clays and the more silicious alluvial clays are of this type. The Porter's Creek (Flatwoods) and the "buckshot" alluvial clays have a slow slaking speed. The Tuscaloosa clays and the Wilcox (La Grange) clays slake rapidly. Clays used for any purpose requiring molding without grinding ought to possess at least a moderate slaking speed. A clay possessing a low slaking speed causes loss of time when tempered either in the wet pan or the pug mill. Such clays must be pulverized in the disintegrator and the granulator before they can be tempered and molded. The bottom clay in most of the surface deposits of the State has a slow slaking speed, and a tendency to form clods, which cannot be entirely removed in the short pug mills in use. For this reason the more successful brick plants are employing the use of one or more forms of pulverizers.

PLASTICITY.

A clay is plastic when it can be easily fashioned by the hands into a desired form, and when it has the property of retaining that form when so fashioned. Dry clay of any form is devoid of plasticity. In order that a clay may become plastic, it must be mixed with a certain amount of water. The quantity of water necessary

PLATE IV.



STIFF-MUD BRICK MACHINE OF THE AUGER TYPE.

to plasticity varies with the physical condition of the clay. Not all clays become plastic when mixed with water. This fact leads to the conclusion that some clays possess an inherent property which renders them plastic by the addition of a certain proportion of water. Experience demonstrates that the plasticity of a clay is not due to a single condition, but that it results from the combined action of a group of factors. Some of these factors are well known, such, for instance, as the presence of uncombined water. There are others, however the nature of which is little known.

FACTORS OF PLASTICITY.

The factors which seem to have the greatest influence upon the plasticity of clay are:

1. *Fineness of Grain.*—Some clays which are non-plastic when taken from the pit, slaked and mixed with water, may be made plastic by reducing them to minute particles before mixing with water. In a similar way the plasticity of all clays may be increased. Fineness of grain is not the only essential factor, however. Some clays of exceedingly fine grain may possess but little plasticity. Experiments have been performed with glass, quartz, mica, limestone and talc to determine whether mere fineness of grain was sufficient to account for plasticity. The results were negative in each case. These substances could not be brought to a condition which would permit them to be molded into forms that would retain their shape.

2. *The Presence of Uncombined Water.*—As has been stated above, a dry clay is not at all plastic but it may become highly plastic when mixed with a certain amount of water. The water acts as a lubricant between the clay particles and thereby permits greater freedom of movement. At the same time the surface tension of the water holds the particles and permits a movement of the clay particles without interrupting the continuity of the clay mass. An effect to be compared to the stretch of a rubber.

3. *The Presence of Combined Water, Bacteria or Some Substance or Condition Which May be Destroyed by Calcining.*—When a plastic clay has been subjected to a temperature sufficient to drive off its combined water it is rendered non-plastic. Nor can its plasticity be

restored by reducing it to fine powder and mixing it with water. This fact proves that some important factor of plasticity has been destroyed by heating the clay. It has been found by practical tests that the plasticity of a clay is increased by "ageing," "mellowing," or "curing" the clay. These are terms applied to the same process which consists in storing the clay for a period of time in a damp cool place. For instance clay which has been stored for a time in a damp cellar is found to have an increased plasticity. This increase is thought to be due to the action of bacteria working in the clay. It is found also that the plasticity of a clay may be increased by the addition of tannin or the addition of an emulsion of straw.

4. *The Presence of Flat and Interlocking Crystals.**—The presence of flat crystals aid by increasing the amount of surface tension of the hydroscopic moisture. This does not apply to the large macroscopic plates of mica which sometimes occur in clay in such abundance as to be detrimental to its plasticity. Crystals which are curved or have angles or serrated edges present interlocking surfaces which increase the tensile strength of the clay and may also increase the plasticity.

A number of methods of determining the degree of plasticity of a clay has been suggested, but none are entirely satisfactory. The old method of determination by hand moulding is still the most reliable.

FUSIBILITY.

Matter may exist in three states, viz., solid, liquid or gas. Water, for example, at ordinary temperatures exists as a liquid. At slightly lower temperatures, it becomes a solid. At higher temperatures, it assumes the form of a gas. When in the solid state if heat be applied the solid becomes a liquid. This transformation is termed fusion. The temperature at which the solid becomes liquid is called the fusion point of the substance. The fusion point of any substance is controlled by pressure. All solids, having a definite chemical composition under a fixed pressure, fuse at a certain definite temperature. This definite temperature is called the fusion point.

Ordinary clays, however, are not of definite chemical composition. Clays are composed of a variety of minerals, each having a definite chemical composition and a definite point of fusion. When heat is

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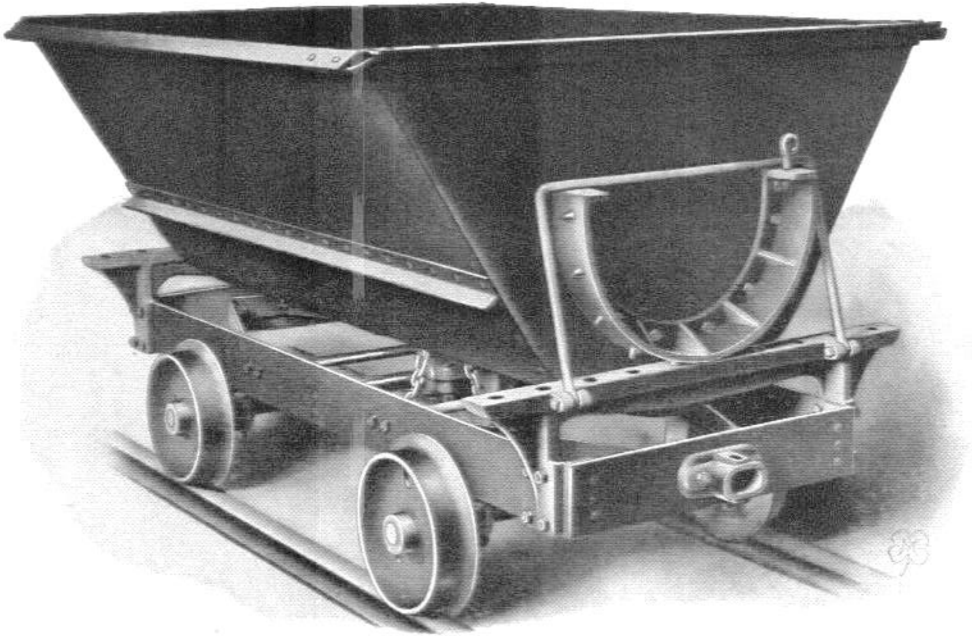
*See Mo. Geol. Survey, Vol. XI, p. 101.

PLATE V.



EITHER-SIDE ROCKER DUMP CAR.

applied to this aggregate of minerals, the one having the lowest fusion point will be the first to fuse. The molten matter which is free to combine may unite with some other mineral or minerals in the clay and form a compound having a lower fusion point than the original compounds. These when molten may act as fluxes for other minerals and the whole clay be reduced to a molten condition at a temperature considerably lower than the fusion point of its most refractory constituents. The change from the solid to the liquid involves the consumption of heat in raising the temperature of the solid to the fusion point. Some heat is consumed as latent heat, some in chemical reactions.

Three stages are usually recognized in the fusion of a clay, namely: incipient fusion, vitrification and viscosity (Wheeler). In the first stage the more fusible particles become soft and upon cooling cement together the more refractory particles, forming a hard mass. In the second stage the clay particles become soft enough to close up all of the pore spaces so that further shrinkage is impossible. When the mass becomes cool, it forms a dense solid body which is glassy on a fractured surface. In the third stage, the clay body becomes so soft as to no longer retain its shape, and flows.

The fusibility of a clay depends on a number of factors, but the most important ones are the amount and kinds of fluxing impurities in the clay and the fineness of the grain.

For determining the temperature of kilns and furnaces and the fusion points of different substances, pyrometers of various kinds are used. One of these is the thermo-electric pyrometer. It consists of a thermo-electric couple which generates an electric current when heated. The intensity of the current increases with the temperature. The current is measured by means of a galvanometer. The thermopile consists of a platinum wire, and a wire composed of 90 per cent platinum and 10 per cent of rhodium. These wires, protected by clay tubes, are inserted into the furnace usually through a small opening in the door.

The fusibility of clays is also determined by the use of Seger cones. These cones are made of a mixture of substances of known fusibility. The cones, together with the clay to be tested, are placed in a furnace or oven and the heat applied. The cone which loses its shape at the moment the clay does determines the fusion point of the clay.

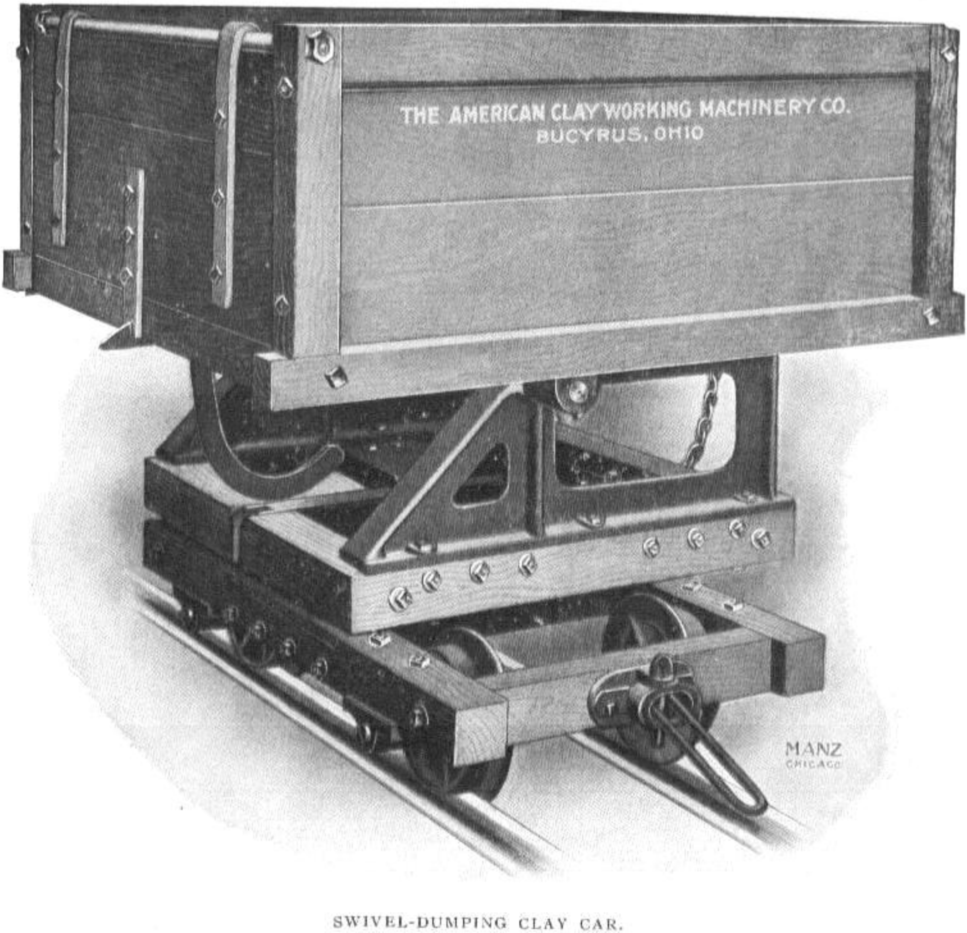
The cones are arranged in a series as given in the following table:

TABLE 10.

COMPOSITION AND FUSING POINTS OF SEGER CONES.

No. of Cone	*Composition*			*Fusing Point*	
				°F	°C
022	$0.5\ NA_2O$ $0.5\ P_2O_5$		$2.0\ SiO_2$ $1.0\ BO$	1,094	590
021	$0.5\ Na_2O$ $0.5\ PbO$	$0.1\ Al_2O_3$	$2.2\ SiO_2$ $1.0\ BO$	1,148	620
020	$0.5\ Na_2O$ $0.5\ PbO$	$0.2\ Al_2O_3$	$2.4\ SiO_2$ $1.0\ BO$	1,202	650
019	$0.5\ Na_2O$ $0.5\ PbO$	$0.3\ Al_2O_3$	$2.6\ SiO_2$ $1.0\ BO$	1,256	680
018	$0.5\ Na_2O$ $0.5\ PbO$	$0.4\ Al_2O_3$	$2.8\ SiO_2$ $1.0\ BO$	1,310	710
017	$0.5\ Na_2O$ $0.5\ PbO$	$0.5\ Al_2O_3$	$3.0\ SiO_2$ $1.0\ BO$	1,364	740
016	$0.5\ Na_2O$ $0.5\ PbO$	$0.55\ Al_2O_3$	$3.1\ SiO_2$ $1.0\ BO$	1,418	770
015	$0.5\ Na_2O$ $0.5\ PbO$	$0.6\ Al_2O_3$	$3.2\ SiO_2$ $1.0\ BO$	1,472	800
014	$0.5\ Na_2O$ $0.5\ PbO$	$0.65\ Al_2O_3$	$3.3\ SiO_2$ $1.0\ BO$	1,526	830
013	$0.5\ Na_2O$ $0.5\ PbO$	$0.7\ Al_2O_3$	$3.4\ SiO_2$ $1.0\ BO$	1,580	860
012	$0.5\ Na_2O$ $0.5\ PbO$	$0.75\ Al_2O_3$	$3.5\ SiO_2$ $1.0\ BO$	1,634	890
011	$0.5\ Na_2O$ $0.5\ PbO$	$0.8\ Al_2O_3$	$3.6\ SiO_2$ $1.0\ BO$	1,688	920
010	$0.3\ K_2O$ $0.7\ CaO$	$0.2\ Fe_2O_3$ $0.3\ Al_2O_3$	$3.50\ SiO_2$ $0.50\ BO$	1,742	950
09	$0.3\ K_2O$ $0.7\ CaO$	$0.2\ Fe_2O_3$ $0.3\ Al_2O_3$	$3.55\ SiO_2$ $0.45\ BO$	1,778	970
08	$0.3\ K_2O$ $0.7\ CaO$	$0.2\ Fe_2O_3$ $0.3\ Al_2O_3$	$3.60\ SiO_2$ $0.40\ BO$	1,814	990
07	$0.3\ K_2O$ $0.7\ CaO$	$0.2\ Fe_2O_3$ $0.3\ Al_2O_3$	$3.65\ SiO_2$ $0.35\ BO$	1,850	1,010
06	$0.3\ K_2O$ $0.7\ CaO$	$0.2\ Fe_2O_3$ $0.3\ Al_2O_3$	$3.70\ SiO_2$ $0.30\ BO$	1,886	1,030
05	$0.3\ K_2O$ $0.7\ CaO$	$0.2\ Fe_2O_3$ $0.3\ Al_2O_3$	$3.75\ SiO_2$ $0.25\ BO$	1,922	1,050
04	$0.3\ K_2O$ $0.7\ CaO$	$0.2\ Fe_2O_3$ $0.3\ Al_2O_3$	$3.80\ SiO_2$ $0.20\ BO$	1,958	1,070
03	$0.3\ K_2O$ $0.7\ CaO$	$0.2\ Fe_2O_3$ $0.3\ Al_2O_3$	$3.85\ SiO_2$ $0.15\ BO$	1,994	1,090
02	$0.3\ K_2O$ $0.7\ CaO$	$0.2\ Fe_2O_3$ $0.3\ Al_2O_3$	$3.90\ SiO_2$ $0.10\ BO$	2,030	1,110
01	$0.3\ K_2O$ $0.7\ CaO$	$0.2\ Fe_2O_3$ $0.3\ Al_2O_3$	$3.95\ SiO_2$ $0.05\ BO$	2,066	1,130
1	$0.3\ K_2O$ $0.7\ CaO$	$0.2\ Fe_2O_3$ $0.3\ Al_2O_3$	$4.0\ SiO_2$	2,102	1,150
2	$0.3\ K_2O$ $0.7\ CaO$	$0.1\ Fe_2O_3$ $0.4\ Al_2O_3$	$4.0\ SiO_2$	2,138	1,170
3	$0.3\ K_2O$ $0.7\ CaO$	$0.05\ Fe_2O_3$ $0.45\ Al_2O_3$	$4.0\ SiO_2$	2,174	1,190
4	$0.3\ K_2O$ $0.7\ CaO$	$0.5\ Al_2O_3$	$4.0\ SiO_2$	2,210	1,210
5	$0.3\ K_2O$ $0.7\ CaO$	$0.5\ Al_2O_3$	$5.0\ SiO_2$	2,246	1,230

PLATE VI.



SWIVEL-DUMPING CLAY CAR.

TABLE 10—Continued.

COMPOSITION AND FUSING POINTS OF SEGER CONES—Continued.

No. of Cone	Composition			Fusing Point	
				°F	°C
6	0.3 K_2O 0.7 CaO	0.6 Al_2O_3	6.0 SiO_2	2,282	1,250
7	0.3 K_2O 0.7 CaO	0.7 Al_2O_3	7.0 SiO_2	2,318	1,270
8	0.3 K_2O 0.7 CaO	0.8 Al_2O_3	8.0 SiO_2	2,354	1,290
9	0.3 K_2O 0.7 CaO	0.9 Al_2O_3	9.0 SiO_2	2,390	1,310
10	0.3 K_2O 0.7 CaO	1.0 Al_2O_3	10.0 SiO_2	2,426	1,330
11	0.3 K_2O 0.7 CaO	1.2 Al_2O_3	12.0 SiO_2	2,462	1,350
12	0.3 K_2O 0.7 CaO	1.4 Al_2O_3	14.0 SiO_2	2,498	1,370
13	0.3 K_2O 0.7 CaO	1.6 Al_2O_3	16.0 SiO_2	2,534	1,390
14	0.3 K_2O 0.7 CaO	1.8 Al_2O_3	18.0 SiO_2	2,570	1,410
15	0.3 K_2O 0.7 CaO	2.1 Al_2O_3	21.0 SiO_2	2,606	1,430
16	0.3 K_2O 0.7 CaO	2.4 Al_2O_3	24.0 SiO_2	2,642	1,450
17	0.3 K_2O 0.7 CaO	2.7 Al_2O_3	27.0 SiO_2	2,678	1,470
18	0.3 K_2O 0.7 CaO	3.1 Al_2O_3	31.0 SiO_2	2,714	1,490
19	0.3 K_2O 0.7 CaO	3.5 Al_2O_3	35.0 SiO_2	2,750	1,510
20	0.3 K_2O 0.7 CaO	3.9 Al_2O_3	39.0 SiO_2	2,786	1,530
21	0.3 K_2O 0.7 CaO	4.4 Al_2O_3	44.0 SiO_2	2,822	1,550
22	0.3 K_2O 0.7 CaO	4.9 Al_2O_3	49.0 SiO_2	2,852	1,570
23	0.3 K_2O 0.7 CaO	5.4 Al_2O_3	54.0 SiO_2	2,894	1,590
24	0.3 K_2O 0.7 CaO	6.0 Al_2O_3	60.0 SiO_2	2,930	1,610
25	0.3 K_2O 0.7 CaO	6.6 Al_2O_3	66.0 SiO_2	2,966	1,630
26	0.3 K_2O 0.7 CaO	7.2 Al_2O_3	72.0 SiO_2	3,002	1,650
27	0.3 K_2O 0.7 CaO	2.0 Al_2O_3	200.0 SiO_2	3,038	1,670
28		Al_2O_3	10.0 SiO_2	3,074	1,690
29		Al_2O_3	8.0 SiO_2	3,110	1,710
30		Al_2O_3	6.0 SiO_2	3,146	1,730
31		Al_2O_3	5.0 SiO_2	3,182	1,750
32		Al_2O_3	4.0 SiO_2	3,218	1,770
33		Al_2O_3	3.0 SiO_2	3,254	1,790
34		Al_2O_3	2.5 SiO_2	3,290	1,810
35		Al_2O_3	2.0 SiO_2	3,326	1,830
36		Al_2O_3	1.5 SiO_2	3,322	1,850

There are also some recording pyrometers in use. The Bristo recording pyrometer, according to the Iron Trade Review (Nov. 8 1906), consists of three distinct parts, viz., the recorder, which is located at the point most convenient for observation of the records, and for changing of the charts; the thermo-electric couple, the fire-end of which is to be inserted into the space where the temperature is to be measured; the leads, consisting of duplex flexible cable for making the electric connection between the records and the fire ends.

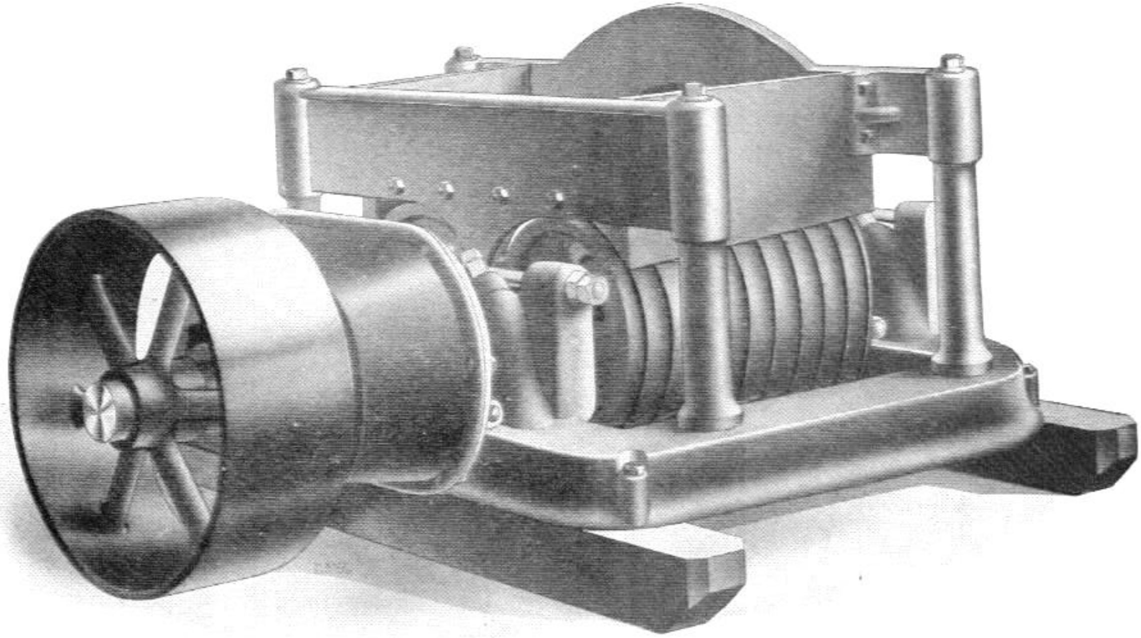
"The thermo-electric couple, which is located where the temperature is to be measured, produces a current of electricity, which is communicated to the recorder through the connecting leads. This current actuates a face, which is so sensitive that a record may be made upon it with a hair. When applied to the instrument, the chart is supported only over a portion of its surface by a semi-circular plate. The clock movement for revolving the chart is contained in the round case behind the semi-circular chart support, and is provided with an auxiliary attachment for periodically vibrating the unsupported portion of the chart, thus bringing the smoked surface into contact with the pointed end of the recorder arm at intervals of a few seconds. By this means, the record of its position is obtained and friction is eliminated.

"The series of marks made by this periodic contact of the recorder arm which removes the carbon from the chart, forms a continuous curve, unless the changes in temperature are extremely rapid. After the record of the day is completed the chart may be removed from the instrument and 'fixed' by immersion in a fixitive solution, which consists of gasoline or alcohol, to which has been added a small amount of concentrated fixitive. After fixing, the charts may be handled and filed without any danger of destroying the record.

"The simplicity of construction insures durability and permanent accuracy and makes the operation of the instrument an easy matter. The protecting case containing the galvanometer is hinged to the back of the recorder. This arrangement prevents injury to the recorder arm while the charts are being changed or the clock wound.

"It should be mentioned that the coating of lampblack on the charts is not sufficient to obscure the graduations, and the edges and center are unsmoked. The charts can therefore be conveniently

PLATE VII.



CONICAL CORRUGATED CLAY CRUSHER.

handled and packed for shipment. The couples employed for ranges not exceeding 2,000 degrees Fahr. are made of special alloys, which are inexpensive, and may be of almost any desired form or length to suit the special requirements. For ranges above 2,000 degrees Fahr. the standard Le Chatelier platinum-rhodium elements are used. Compound couples may be used to reduce the high cost of the platinum-rhodium element. The inexpensive alloys employed for the extension of the couple are such that the two secondary thermo-electric effects at the junctions with the platinum and the platinum-rhodium elements neutralize each other if the temperature at these junctions does not exceed 1,200 degrees Fahr. The indications on the instrument will be the same as if the whole couple had been made of the more expensive metals. Where there are varying temperatures at the cold end of the couple, a mercury compensator is used, which automatically changes the resistance of the circuit, so that no connection is necessary for the working range of the instrument."

MECHANICAL ANALYSIS.

Clay is a mechanical mixture of mineral particles. These particles vary in size from those which are easily detected by the unaided eye to those which may be seen only by the use of a powerful microscope. The mechanical analysis of a clay consists in the separation of these particles into various groups. Because of the extreme degree of gradation in the size of the particles a complete separation is not possible, and it is not essential for the purposes of the clay worker.

In the mechanical analysis of soils the following methods of grouping have been employed and the same or similar grouping are applicable, and have been applied, in the separation of clays:

TABLE 11.

METHODS OF GROUPING IN MECHANICAL ANALYSIS.

No. of Group	*Hilgard*	*Hopkins*	*Osborne*	*Whitney*	*Name of Group*
1	3.0 m.m.	1.0 m.m.	3.0 m.m.	2.0 m.m.	Fine gravel
2	1.0 m.m.	.32 m.m.	1.0 m.m.	1.0 m.m.	Coarse sand
3	.5 m.m.	.1 m.m.	.5 m.m.	.5 m.m.	Medium sand
4	.3 m.m.	.032 m.	.25 m.m.	.25 m.m.	Fine sand
5	.16 m.m.	.01 m.m.	.05 m.m.	.01 m.m.	Very fine sand
6	.12 m.m.	.0032 m.	.01 m.m.	.05 m.m.	Silt
7	.072 m.	.001 m.		.005	Clay
8	.047 m.				
9	.036 m.				
10	.025 m.				
11	.016 m.				
12	.010 m.				

A number of methods of mechanical analyses has been employed. They may be classified under three heads, viz: the beaker or decantation method used by Osborne and others; the elutriation method of Hilgard, and the centrifugal method used by the United States Bureau of Soils. (See Bul. 24, U. S. Agric. Dept.)

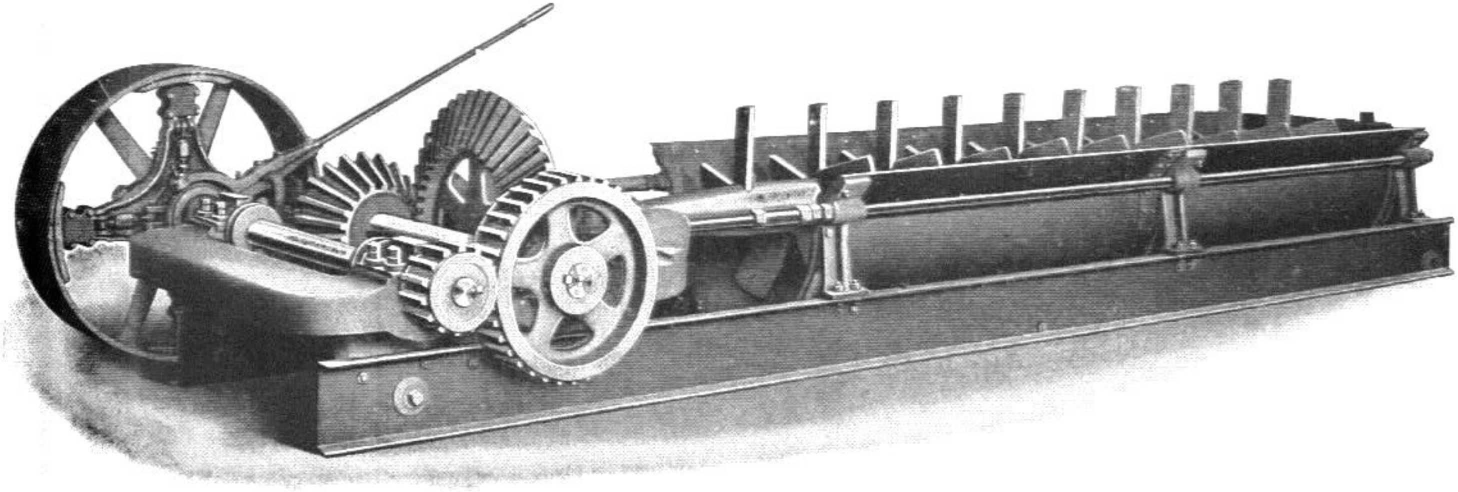
In the Osborne method of analysis the soil to be analyzed is placed in a cylinder containing water. After being agitated, the suspended particles are allowed to settle until only those of the smallest group remain in suspension. The water is then drawn off and the process is repeated until all the particles belonging to this group have been removed. Then the next larger group is removed. The water is evaporated, the particles dried and weighed and the per cent which they form of the whole determined. All of the groups of finer particles are removed in this way. The larger particles are separated by means of sieves.

Hilgard's elutriation consists of a vertical cylinder containing a rapidly revolving stirrer at the bottom. At the bottom a stream of water is forced through this cylinder at a given velocity. The size of the particles carried out by the current depends on the velocity of the current; *i. e.*, a velocity of 4 m.m. per second is sufficient to carry out all particles of quartz less than 0.25 m.m. in diameter, and a velocity of 64 m.m. per second would carry out particles 2 m.m. in diameter. The elutriatior is used for separating particles larger than 0.01 m.m. in diameter. The finer particles are separated by subsidence.

In the centrifugal method, the soil is first disintegrated by the use of a mechanical shaker, an instrument for shaking samples of soil in water, for a period of time sufficient to cause the complete separation of all aggregations of particles. The water containing the suspended particles of soil is then placed in the test tubes of a centrifugal machine. The machine is rotated until all of the coarse particles are thrown down. The particles of the finest group are decanted off. The process is repeated until only the coarser material remains and this is separated by the use of sieves.

By the use of a method suggested by Beyer and Williams (see Vol. XIV, Iowa Geol. Sur.) the mechanical analysis of a number of types of Mississippi clays was made with the following results:

PLATE VIII.



HORIZONTAL GRANULATOR.

TABLE 12.

MECHANICAL ANALYSES OF MISSISSIPPI CLAYS.

		Per Cent						
Formation	*Locality*	*Fine Gravel*	*Coarse Sand*	*Medium Sand*	*Fine Sand*	*Very Fine Sand*	*Silt*	*Clay*
Brown loam	Jackson	0.0	0.5	0.2	10	5	60	22
Brown loam	Yazoo	0.0	0.5	0.3	2	4	75	15
Lafayette	Newton	0.5	2.0	12.0	53	8	20	5
Flatwoods	Bradley	...	2.0	3.0	10	50	13	10
Selma	Starkville	1.0	2.0	4.0	8	9	40	20
Alluvium (Buckshot)	Moorhead	0.0	0.2	1.0	2	2	58	30
Alluvium (Buckshot)	Greenwood	0.1	1.0	1.5	2	2	42	45

BONDING POWER.

The bonding power of a clay is its power to hold together particles of non-plastic materials. The bonding power of a clay is dependent in a measure on the amount of clay substance which the clay contains. It also depends on the size of the grain of the inert matter added. To illustrate, a larger amount of finely divided sand may be added to a clay without decreasing its plasticity and bonding power than of coarse sand. It is often necessary, in order to secure the proper shrinkage and drying capacity in a clay ware, to use a mixture of two clays or to add sand or grog to the clay. The quantity of the inert matter which may be added without seriously impairing the strength of the ware will depend on the bonding power of the clay. Bonding power is an essential property.

TENSILE STRENGTH.

The amount of resistance which a clay offers to pull is termed its tensile strength. Wet clays possess this property to a slight degree; dry clays to a greater degree, and burned clays to a still higher degree. Were it not for this property it would be impossible to handle clay ware because of the ease with which they would be cracked or broken. The tensile strength of a clay is not due to any chemical change but to the physical cohesion of its particles. It was formerly thought that the tensile strength of a clay was a safe guide to plasticity, but it is no longer so, for the reason that many very plastic clays have been found to have a very low tensile strength.

In preparing clay for the tensile strength test, the clay is first rolled or crushed in a mortar until it is in the condition of a powder.

Then in order to separate all particles of a certain maximum size, the powder is passed through a sieve. The sieve used in our experiments has only forty meshes to the inch. To this powdered clay water was added in sufficient quantity to form a plastic body. The wet clay was then molded in brass molds into brickettes. The form of the mold is seen in Figure 1.

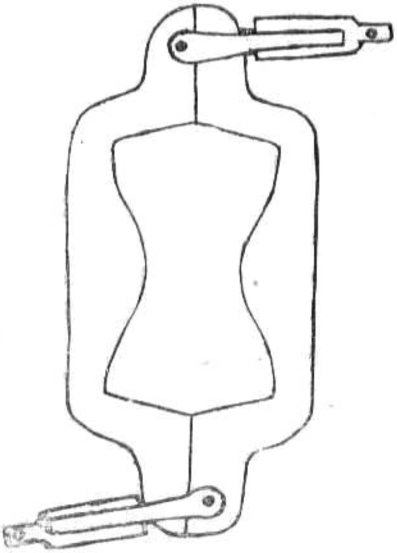
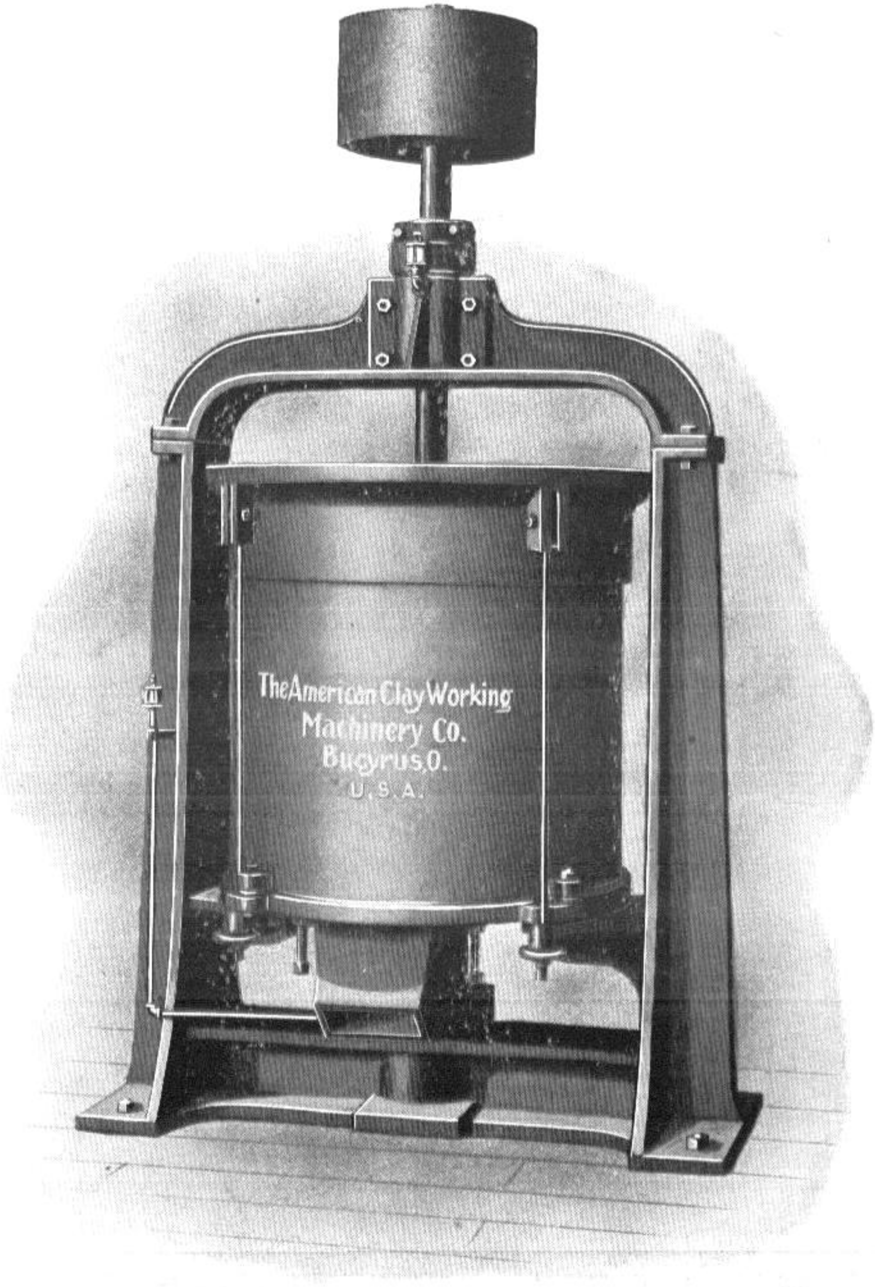


FIGURE 1. BRICKETTE MOLD.

Two methods of placing the clay in the molds were tried. In the first the brass mold was oiled and placed upon an oiled glass surface. The clay was then pressed into the mold by the fingers and by the use of a small wooden tamp cut to fit the mold. The clay was cut off on a level with the top of the mold by the use of a putty knife. By moistening the blade of the knife and passing it across the surface of the clay, both surfaces were made perfectly smooth. By the use of the tamp the clay was then pressed out of the mold upon an oiled glass surface. After remaining in this position for a couple of hours the brickettes were placed upon edge in order that both sides might dry equally. This is necessary in order to prevent cracking or warping. This method of molding was found unsatisfactory because of the difficulty in preventing laminations which would weaken the

PLATE IX.



REDUCTION MILL.

tensile strength of the brickette. Flaws due to air blebs were also produced.

By following a method of molding suggested by Orton* better results were obtained. The clay was now wedged into blocks about 3 inches long by 1¼ inches square. These blocks were now clamped into the molds and patted in until the clay completely filled the mold. The treatment from this point on was the same as in the other method. In the case of every brick prepared in this way the broken section of the brickette was found to be homogenous in structure. A number of clays were tested by both methods. The relative merits of the two methods may be determined from the following comparison of results obtained from tests made on a West Point brick clay. Twelve brickettes molded by the first method varied in tensile strength from 60 pounds per square inch to 151 pounds per square inch and the average tensile strength of the twelve was 144 pounds per square inch. Twelve brickettes molded by the second method varied in tensile strength from 122 pounds per square inch to 181 pounds per square inch and the average tensile strength of the twelve brickettes was 152 pounds per square inch.

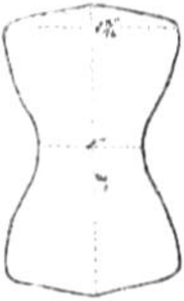


FIGURE 2. OUTLINE OF BRICKETTE.

The form of the brickette is shown in Figure 2. In its longest dimension it is three inches. The cross section of the brickette at the middle, if there is no shrinkage, is one square inch. The shoulders of the brickette have a width of 1 11-16 inches. The thickness of the brickette at any point is one inch, less the shrinkage. After air

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*Transactions of Am. Cer. Soc., Vol. II, p. 110.

drying the brickettes were placed in an oven and the hygroscopic moisture driven out at the temperature of boiling water. The brickettes were then measured to obtain the amount of shrinkage.

The brickettes were tested by the use of a Fairbank's Cement Machine. The brickettes were placed in the clips of the machine and subjected to a gradually increasing tension. The increase of tension is secured by the weight of shot discharging into the pail on the lever arm. At the moment of breaking, the discharge of shot is stopped automatically. If the brickettes have undergone much shrinkage, they will not fit the clips of the machine and it will be necessary to bush them. This may be done by placing cardboard or blotter paper between the brickette and the clip.

The tensile strength is expressed in pounds per square inch and the shrinkage was calculated and taken into account in estimating the tensile strength of the brickettes.

In the majority of tests twelve brickettes of raw clay were tested, and twelve burned brickettes. The average of these twelve tests were taken. The results of these tests are found under the discussion of the physical properties of each clay.

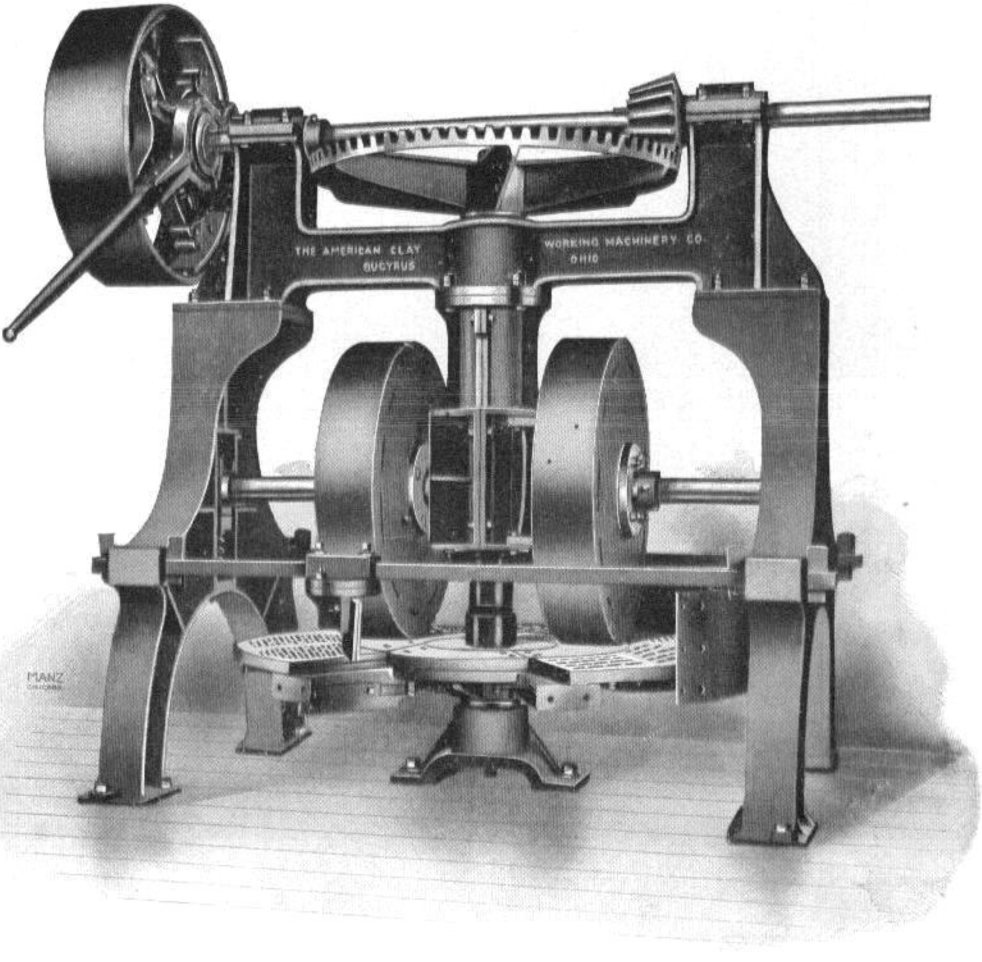
TABLE 13.

TENSILE STRENGTH OF MISSISSIPPI BRICK CLAYS.

	Tensile Strength in Pounds per Square Inch	
Formation	*Raw Clay*	*Burned Clay*
Yazoo alluvium ("buckshot" type)	188	484
Yazoo alluvium (sandy type)	90	157
Jackson residual clay	78	112
Lafayette	94	212
Flatwoods (Porter's Creek)	116	185
Selma residual	133	333
Buhrstone	187	181
Brown loam	78	133

The figures given in this table represent the average of a large number of tests made on brickettes molded from clay collected from a great many localities. The individual strength of these clays is given in the discussion of the physical properties of each clay. The brickettes tested in the burned condition were burned at a good red heat, but because of the differences in the clays all of the brickettes were not of equal hardness. Some of them exhibited a lower tensile strength than if they had been burned at a slightly higher tempera-

PLATE X.



DRY PAN.

ture. The greater number of brickettes would have been classed as medium; a few were soft; none, however, were hard.

POROSITY.

A porous clay is one which contains considerable space not occupied by clay particles. This unoccupied space is called pore space and its volume depends on the size and shape of the clay particles. The maximum volume of pore space would be reached in a clay containing spherical grains of equal size. However, the shape and size of the grains in clays are extremely variable. The quartz grains are usually rounded, water-worn particles, but in some residual clays they are sharp angled. The mica grains are little flat crystals with irregular edges. The kaolinite may be flat or irregular in shape. The feldspar grains are either more or less rounded or irregular. The grains are in contact only at certain points, thus leaving spaces between the particles. These pores are in connection with other pores, and by a long chain of such connections irregular tubes are formed. These tubes are of capillary size, and the water which is within the clay may pass to the surface by capillarity.

Porosity is an important property in clays. The amount of water required for tempering the clay depends in a large measure on its porosity. The air-shrinkage of the clay is brought about by the loss of this water. The speed of tempering and the speed of drying depend on the porosity. The larger the pores the more readily the water is taken up and given off

CHAPTER IV.

PROCESSES OF CLAY MANUFACTURE.

MINING.

The method of mining clay for use in the manufacture of brick varies with the conditions under which the clay occurs and also with other conditions, such as the capacity of the plant. For example, drilling and blasting may be necessary in the mining of a hard shale, while undermining with pick and shovel may be used to great advantage in the mining of many of the incoherent surface clays.

Clays are mined either by surface diggings or by underground workings.

Underground mining may be conducted by the use of vertical shafts, through which the clay is usually brought to surface by the use of buckets attached by a rope to a windlass. If the clay should outcrop on the side or near the base of a hill, it may be mined by the use of drifts or by the use of tunnels.

The different methods of surface mining may be classed as the (1) pick and shovel method, (2) plow and scraper method, and (3) steam shovel method.

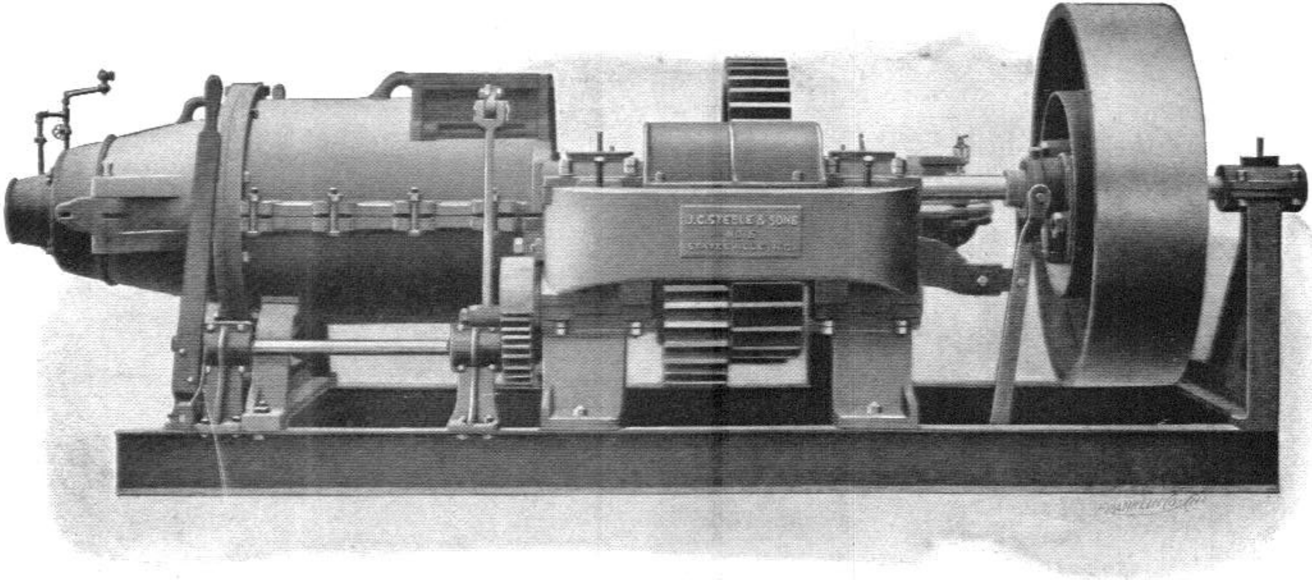
Pick and Shovel Method.—Usually the full thickness of the clay is exposed at once by digging a pit to the bottom of the clay bed. A sloping entrance to the pit is left on one side to facilitate hauling. If the clay be uniform in quality it is undermined near the base with a pick, causing the clay above to break off and thus securing the aid of gravity in the prosecution of the work. If there are two or more kinds of clay which it is desirable to mix, the upper layer may be removed for a short distance back, then the lower clay undermined. The two clays are thus kept separate and may be mixed in any desired proportion. In some clay pits nearly every spade length in depth represents a change in quality of clay, so that mining may be conducted on five or six levels. In many surface clays the upper portion of the bed is so sandy that it may be readily mined with the spade, but the bottom clay may be a stiff joint clay which will require the use of pick and shovel.

Plow and Scraper Method.—The usual method of mining surface clays is by the use of the plow and scraper. The size of the plow and of the scraper, and the number of horses employed, depend on the capacity of the plant. The area of the proposed pit is first plowed and the soil removed. Then it is replowed and the clay taken either directly to the machine or to the mellowing shed, as the case may be, or it is taken to a dump and thrown into a car which is used to transport the clay to a shed or machine.

If the clay be uniform, this process of plowing and scraping may continue until the bottom of the clay stratum is reached. It frequently happens that there is a marked difference in quality between the clay in the top layers and that in the lower layers of the clay stratum. Under these circumstances the best results may be obtained only by mixing the top and bottom clays in certain proportions. In order to secure the proper mixture it may be necessary to remove the top layers from a portion of the pit. This top clay so removed may be placed convenient to the machine or the dump, so that it may be used later and the labor of its removal not wholly lost. The clay is now taken partly from the bottom layers and partly from the top in the proportion to give the best results. Usually the sides of the pit are kept sloping, so that the plow may cross the top clay diagonally, cross the bottom clay near the center of the pit and pass across the top clay again at the farther side.

Steam Shovel Method.—In plants of large capacity the steam shovel is employed in mining operations. Its use generally means a great economy in labor. The first cost makes it prohibitive for a plant of small size. To operate the steam shovel a track is laid on the bottom of the pit, and the clay scooped from top to bottom of the wall or face of the pit. The clay pit is usually enlarged in a semi-circle. The track upon which the shovel runs is laid parallel with the peripherv and advanced as the wall advances. Inside of the steam shovel track is another track for the cars. When the shovel is loaded, a swinging crane moves it over the car. When in the proper position the bottom of the shovel is opened and the clay emptied into the car. The steam shovel of the dipper type has a radius of action of fifteen

Plate XI.



STIFF-MUD BRICK MACHINE, END CUT.

feet and greater. A cut is first made for a certain distance, extending to the bottom of the clay stratum. A track is laid upon the surface of the cut, and upon this track the steam shovel is placed. The shovel dips the clay from one bank and delivers it to cars on the opposite side. As the face of the cut advances, the track is moved forward and the clay removed from gradually increasing circles. The clay is well mixed, as the shovel takes clay from all parts of the face at each dip.

TRANSPORTATION.

A number of methods for the transportation of raw clay from the pit to the machine are employed. These may be classed as (1) wheelbarrow haulage, (2) cart haulage, (3) wagon haulage, (4) scraper haulage, (5) car haulage.

Wheelbarrow Haulage.—Wheelbarrows moved by hand power are employed to a very limited extent in some plants. Usually the plants are of small capacity, and the distance which the clay must be moved very short. Some large plants use wheelbarrows to transport clays from storage bins to pug mills.

Cart Haulage.—Hauling clay in a cart is not an uncommon way of transporting clays The carts are provided with two wheels, and are strongly constructed. They are usually drawn by one mule, though two mules hitched tandem are sometimes employed. The cart is provided with stout shafts and the harness is arranged so that the shafts may be tilted up and the clay dumped out at the rear end of the cart. This saves the labor of shoveling in unloading. The mule is generally driven by a boy who sits on the front end-board of the cart. The clay digger loads the carts, and a man may be employed to dump the carts as they come to the ring pit or pug mill. This method of haulage is not employed for great distances, and only on comparatively level ground.

Wagon Haulage.—Two-horse wagons are employed by some brick manufacturers. They are used where the distance from the plant to the pit is considerable, and the road rough. This is not an economical form of haulage for a plant of large capacity. Two-horse or four-horse wagons are also employed in transporting clay from railroad cars to the plant.

Scraper Haulage.—If the clay used is a surface clay and the pit easily accessible to the machine, two-horse drag scrapers may be employed to move the clay. They are also employed for loading the cars used by many plants.

Wheel scrapers are employed in many dry-press plants, in which it is desirable to store the clay in advance of use. Two horses are employed to draw them. The use of the scraper facilitates the mixing of the clay. It is very frequently desirable to mix a plastic clay and a non-plastic clay. A layer of one kind of clay is spread over the floor of the storing shed. This is covered with a layer of the other kind of clay, and the process repeated until the clay reaches the desired height in the shed. In using the clay, a section is taken from top to bottom of the stored clay. This method makes it possible to secure the proper proportion of each clay, and the mixing becomes more thorough in passing through the machinery.

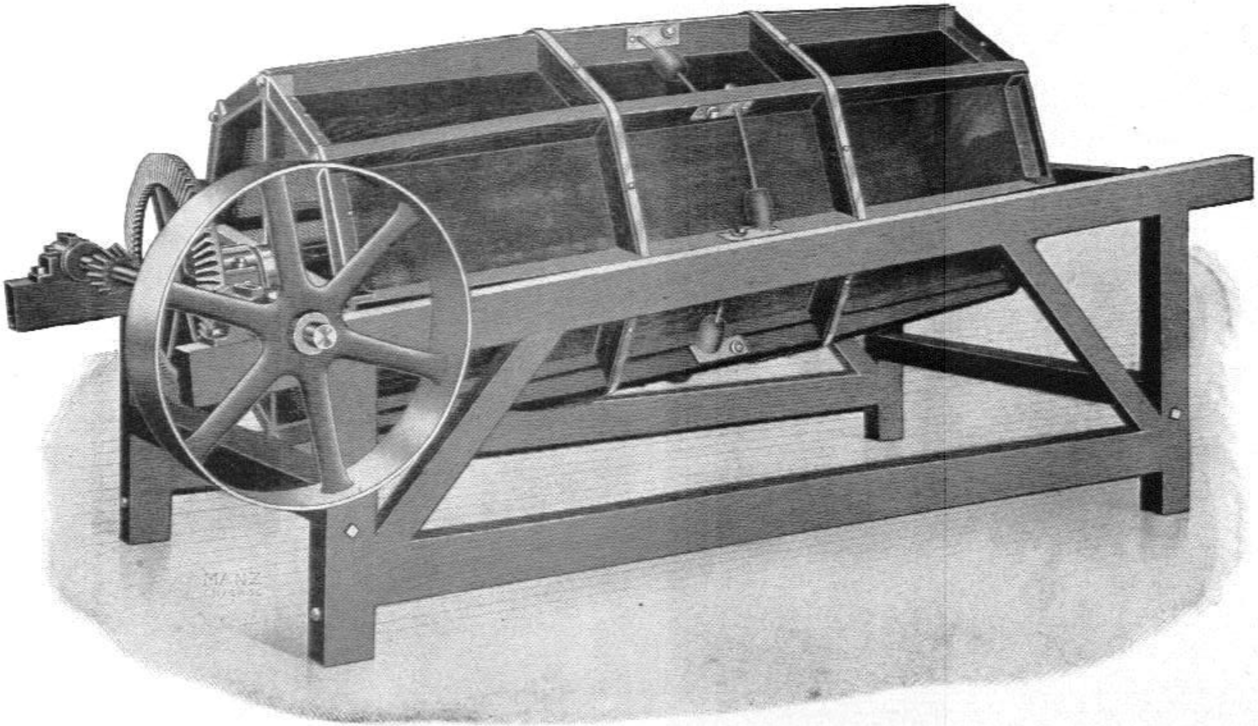
The clay gatherer is used in some plants. This is a cylindrical wheeled scraper which gathers the clay and transports it to the plant.

Car Haulage.—This form of haulage is used in nearly all plants of large daily capacity. The track consists of two parallel lines of wooden, or more often iron, rails of light weight laid on crossties. The rails vary in weight from 12 to 20 pounds, though it is generally not considered economy to use a rail lighter than 20 pounds, since the car wheels are worn so much more rapidly with the lighter rail. The ties are usually 4 x 4 or 4 x 5, oak or pine pieces. The cars used vary in capacity from one to three cubic yards. Most of the cars now in use have the boxes mounted on pivots so that they may be swung around and dumped from any position. They may be dumped forward, backward or to either side.

Selection of Timber for Tracks.—The selection of timber for the ties in the larger plants for the haulage track and the steam shovel track becomes an important matter. It is economy to select the most durable timber for such situations.

The durability of ties varies with the conditions. The kind of wood used is one of the determinative factors of its durability. Experiments tend to show that under like conditions different woods will last as follows:

PLATE XII.



ROTARY CLAY SCREEN OF THE OCTAGON FORM.

TABLE 14.

DURABILITY OF DIFFERENT WOODS.

Ash, beech and maple	4 years
Spruce, hemlock, red and black oaks	5 "
Elm and long leaf pine	6 "
Cherry, black walnut, locust and tamarack	7 "
White oak and chestnut oak	8 "
Chestnut	8 "
Black locust, cypress and red cedar	10 "
Redwood	12 "

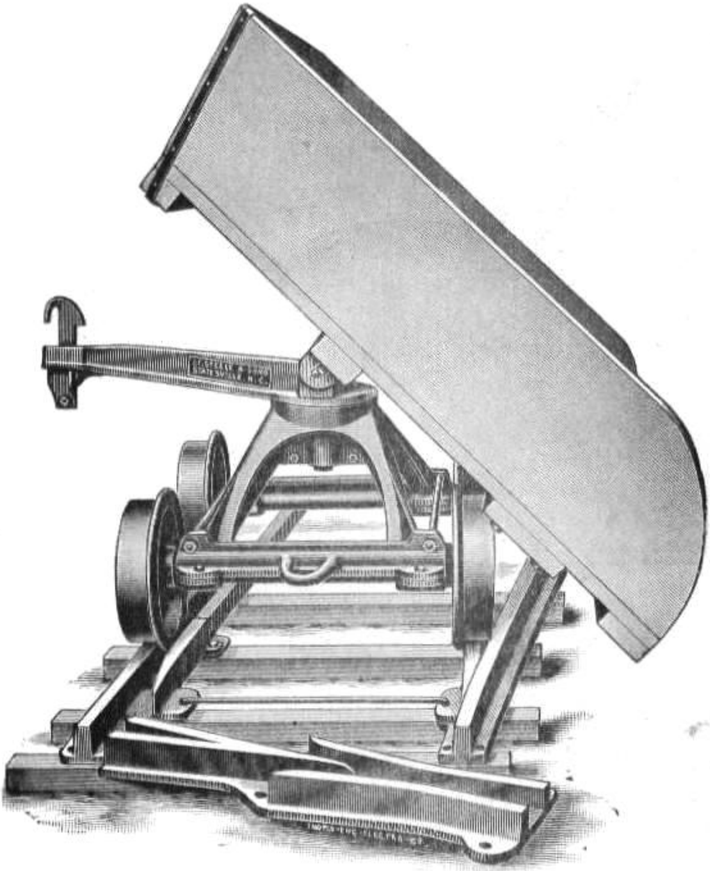


FIGURE 3. SIDE-DUMPING CLAY CAR.

Decay in wood is produced by the growth of forms called fungi. The conditions favorable to the growth of fungi are (1) abundant moisture, (2) an optimum temperature, and (3) the presence of air.

The optimum temperature for most species is about 80°F. Fungus decay may be prevented by keeping the timber dry, or at a temperature exceeding 100°F., or by immersing in water to exclude the air.

Such methods of destroying the conditions favorable to fungus growth are not practicable in the case of ties, and it becomes necessary to resort to some method of excluding the moisture. To accomplish this the timber is first kiln dried and then treated to an immersion in creosote, tar or paint, which prevents the entrance of moisture.

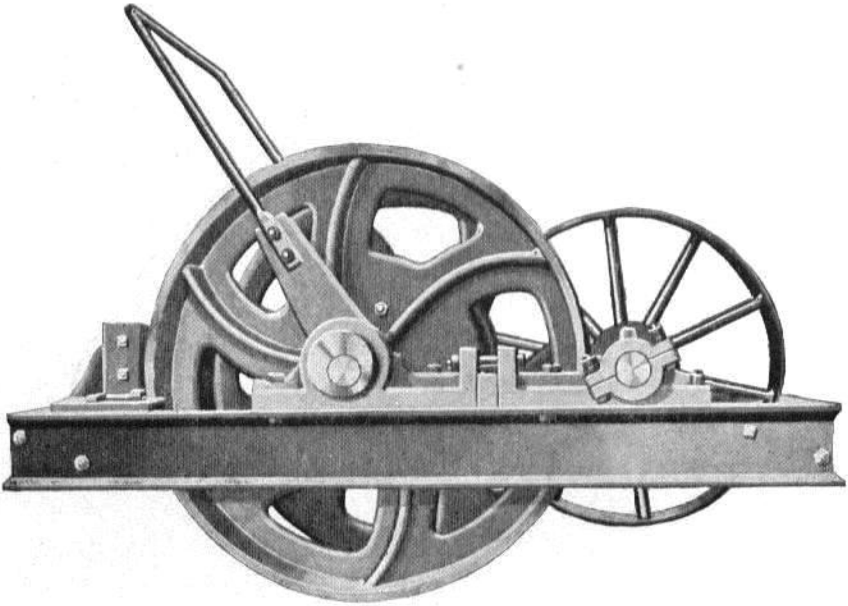
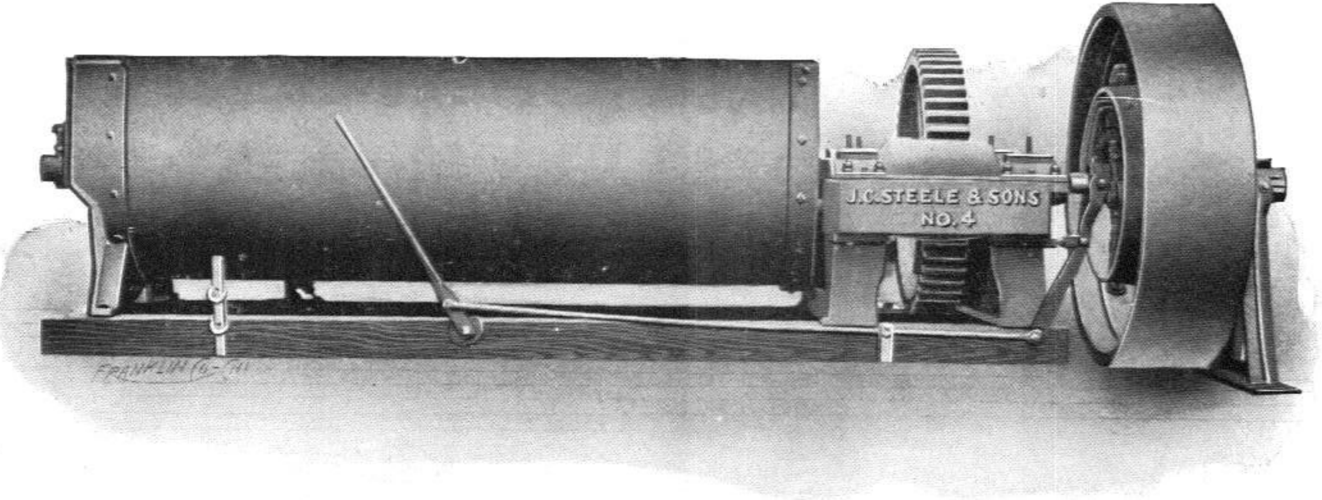


FIGURE 4. DOUBLE-FRICTION HOISTING DRUM.

Sap wood decays much more readily and rapidly than heart wood. This fact should be borne in mind when selecting timber for damp places. It should also be remembered that certain species are more durable than others. Timbers are sometimes preserved by steaming to open the pores, and then forcing a combination of bichloride of zinc and of creosote into the pores under pressure. These substances "poison" the wood so that the fungi cannot feed upon it. The longevity of the wood may thus be increased two or three fold.

Plate XIII.



PUG MILL.

GRINDING.

Clays are reduced to a pulverulent or granular form by the use of a variety of machines. The following names are applied to such machines: crushers, rolls, disintegrators, granulators, pulverizers, dry pans, ball machines and reduction mills. For some of these to do effective work the clay must be thoroughly air-dried, but some of them may be used for pulverizing damp clay.

Crushers.—Jaw crushers are employed for breaking up indurated clays or shales. They contain a pair of movable jaws between which the clay is crushed. These jaws open wide at the top, and gradually close in as the bottom is approached. Another type has a stationery jaw in the shape of an inverted hollow cone in which a conical movable jaw works upon a pivot with an up-and-down movement alternately widening and narrowing the space between the jaws. (See Plate VII.)

Rolls.—Rolls consist of two or more iron or steel cylinders of rolls between which the clay is crushed. In some machines there are two cylinders which are made to revolve in opposite directions. The clay is fed into a hopper on the upper side of the rolls, and is crushed as it passes between the rolls. In some machines two small cylinders are placed above two large ones. The space between the top cylinders is greater than that between the large ones. The rolls run at different speeds, one having twice or three times the speed of the other. The space between the rolls is regulated by having rubber or coil springs. The distance between the rolls may be regulated for different kinds of clay. The rolls are provided with scrapers for keeping them clean. The surface of the rolls may be smooth, corrugated, conical, toothed or conical and corrugated. The capacity varies from 1,000 to 5,000 bricks per hour. The speed of the rolls is ordinarily from 150 to 300 revolutions per minute.

Granulators.—Granulators are horizontal, semi-cylindrical shells in which a long shaft revolves centrally. To the shaft are attached knives for cutting and tearing the clay. The angle at which the knives are set upon the shaft determines the speed or movement of the clay through the granulator. The clay is fed into the rear end of the machine, and crushed and shoved forward by the knives. The knives are ground and polished to prevent the clay from sticking.

The speed of the knives is from 150 to 300 revolutions per minute. The capacity varies from 3,000 to 15,000 brick per hour.

Disintegrators.—Disintegrators may be used for handling dry or damp clay. (See Plate XVI.) The machine is provided with a large roller which moves at a low rate of speed, and feeds the clay to a smaller roller which is provided with steel cutters. The cutters may be replaced as they become worn. The disintegrating roller is moved at a high rate of speed, and the cutters strike the clay and break it up. The distance between the rollers is adjusted by moving the feed roller. The speed of the feed roller is 30 or 40 revolutions per minute, while that of the disintegrator roller is from 400 to 600.

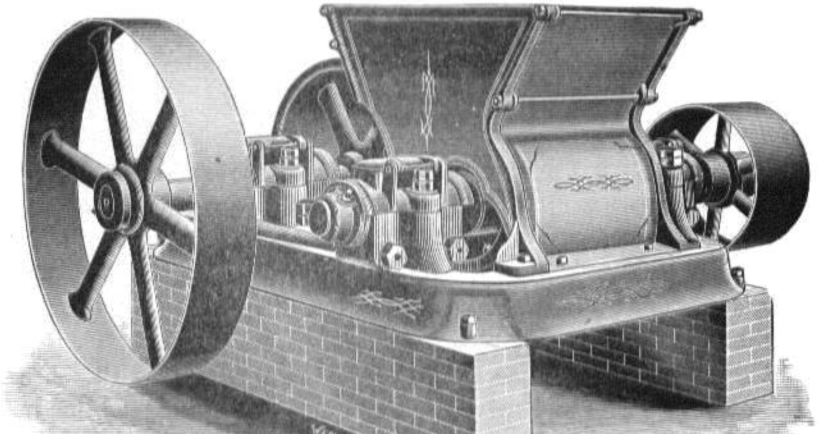


FIGURE 5. CLAY DISINTEGRATOR.

The combined disintegrator and pulverizer consist of "several oppositely revolving cages formed of round bars, reinforced with iron rings and secured to heavy cast circular discs. The bars of one set of cages project between the bars of the opposite cages. No grinding or crushing surface is presented; the material to be disintegrated is received into the inner cage, and by the centrifugal force created by the rapidly revolving cages, the material is projected through the cages and against each other." This action by force of impact breaks up the clay. The differential speed between the hopper side

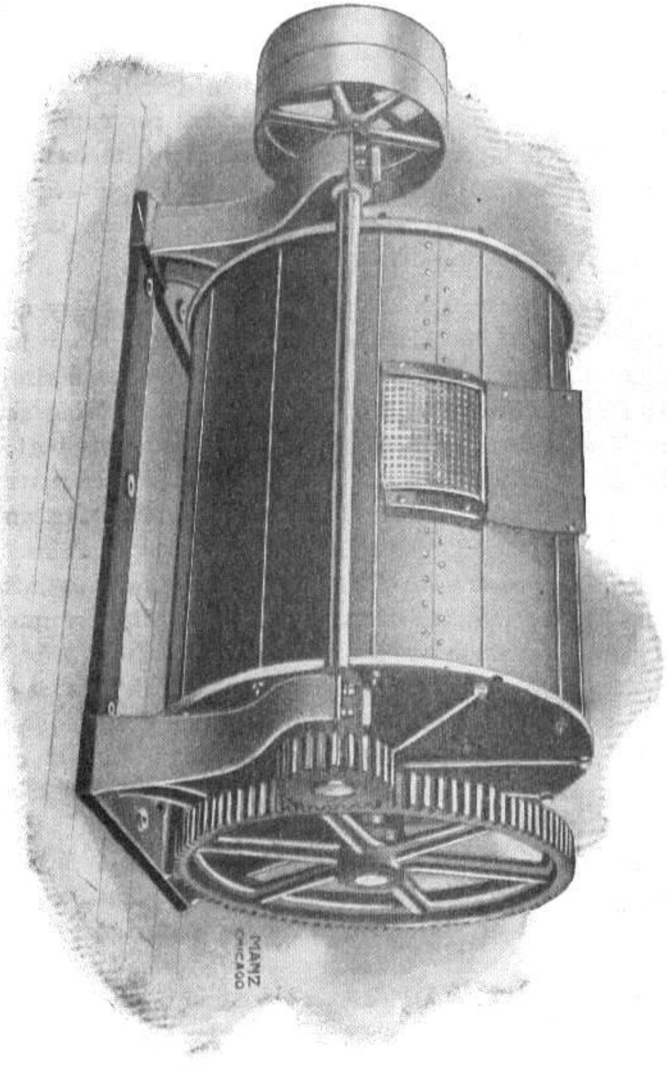


FIGURE 6. PEBBLE CYLINDER MACHINE.

and the opposite side is usually about 100 revolutions per minute. The capacity of the machines vary from 1,000 to 10,000 brick per hour. (See Figure 5 and Plate XVI.)

Reduction Mills.- Reduction mills are used for grinding dry clay. They consist of a cylindrical chamber with a perforated bottom plate. Above the bottom a perforated grinding plate revolves with a speed of from 300 to 600 revolutions per minute. The clay which is thrown upon the plate furnishes by its own weight the friction necessary for attrition. As the clay is pulverized, it drops through the perforations, or by centrifugal action is thrown out between the rings. (See Plate IX.)

Dry Pans.—Dry pans are used for pulverizing dry clays, grog, shales and other hard materials. They consist of revolving pans, containing two large rollers or wheels supported on horizontal axes. The pan is attached centrally to a vertical revolving shaft. The motion of the pan is conveyed to the wheels. The bottom of the pan in the path of the wheels is solid. The outer portion of the bottom is perforated. The pulverized clay, being thrown outward by centrifugal action, drops through the perforations. Scrapers traversing the bottom of the pan throw the clay in front of the wheels. The pans vary in diameter from 5 to 9 feet. The perforated bottom of the pan is generally made in sections which may be removed, and replaced by sections of different mesh. The wheels or mullers have tires which are removable, and may be renewed when badly worn. The space between the wheels and the bottom of the pan may be adjusted by the aid of springs and adjusting screws. The gearing and pulley shaft are generally placed at the top of the frame, which may consist either of wood or steel, but in large machines the latter is used almost exclusively. The machines vary in weight from two to fifteen tons. Dry pans are sometimes run in pairs, both pans being operated by the same pulley, the latter being on the center of the shaft with a pinion on each end. (See Plate X.)

Ball Mills.—Ball mills are sometimes employed for grinding fine grades of clay or glazes. They consist of a cylinder set in a frame, and revolved by means of a driving pulley, attached by appropriate gearing. The clay is placed in the cylinder through an opening in one end of the cylinder. Hard flint pebbles or porcelain balls are put into the cylinder, and as the cylinder revolves these strike the clay and pulverize it. When it has reached the proper degree of fineness, it leaves the cylinder through a perforated plate. In this type of ball mill, the action is continuous. In the periodic type, the clay is put in, and none removed until all has reached the proper degree of fineness.

TABLE 15.

CRUSHING MACHINERY USED IN MISSISSIPPI BRICK PLANTS.

1. Number of plants using rolls	2
2. " " " " disintegrators	20
3. " " " " granulators	15
4. " " " " dry pans	2
5. " " " " reduction mills	0
6. " " " " ball mills	0
7. " " " " no separate crushers	41
Total number of plants reporting	65

SCREENING.

Screens are used in few plants in this State outside of pressed brick plants. They are used in order that the pulverized clay may not contain particles larger than a certain maximum size. The perforated materials used in the screen may be either wire netting or perforated iron or steel plates.

Screens may be classed as rotary, inclined stationary, inclined vibratory or endless revolving.

Rotary Screens.—Rotary screens may be cylindrical, conical or polygonal. The screens are mounted in strong frames of heavy timber, within which they revolve. Some are provided with a short driving shaft to which a driving pulley is attached by gearing. Others do not have shafts, but the driving pulley is attached by a chain which passes around a cogged flange on the end of the screen. The screen is mounted on grooved trunions, a pair located at each end of the screen. The cylinders vary in length usually from 5 to 9 feet. The end of the screen opposite the gearing is elevated so that as the screen revolves the clay moves longitudinally through the screen. The tailings, material too coarse to pass through the perforations of the screen, pass out at the end of the screen, and are carried back to the grinder by means of a chute or other form of conveyor. The fine clay drops through the screen into a bin below. The rotary screens are kept clean by means of metal brushes or some automatic jarring device. (See Plate XII.)

Inclined Stationary Screen.—The inclined stationary screen is in the form of an inclined floor over which the crushed clay passes under the influence of gravity. The inclination of the screen will determine the velocity of the clay and also the maximum size of grain of the screened clay. The lower the velocity of the clay the smaller the size of the largest particle passing the screen. If the screen be placed at a low degree of inclination, more of the clay will adhere to the surface of the screen. Sometimes a steam coil is placed on the under side of the screen to heat the screen, or prevent the clay from sticking to its surface. The pulverized clay drops through the screen into a bin, while the tailings are carried from the end of the screen back to the crusher.

Inclined Vibratory Screen.—The inclined vibratory screen has a much lower angle of inclination than the stationary, and for that reason requires a constant movement of the screen to aid in the movement of the clay across it. The vibratory movements may be either transverse or longitudinal. *"This movement is imparted by either an eccentric or crank. The clay is thrown on the screen, and if the impulse given to the screen be longitudinal, the clay is gradually carried downwards by repeated little jumps in the direction of vibration. If the vibration be transverse, the clay will be thrown from side to side, and will move to the lower end of the screen more slowly than in the former case. Within limits, the longer the time required for the clay to pass the length of the screen, the more perfectly will the screening be accomplished, and in all instances with this style of screen, the maximum size of the particles passing it is approximately the diameter of the mesh. It is recommended in the use of this class of screen that sufficient play be provided in the vibrating device that a brief pause is allowed at the extremity of each swing. There should be provided solid blocks or posts, against which the screen is brought to a sudden stop with each vibration. The repeated jar thus imparted with each swing is very effective in keeping the meshes open, especially if the clay happens to be damp."

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*Beyer and Williams, Geol. Sur. Iowa, An. Rept. XIV, 1903, p. 180.

Revolving Screen.—The revolving screen is made up of a large number of screen plates attached at the ends to two endless chains. The clay is delivered from a spout upon a spreading table from which it descends to the screen. As the screen is revolved, the screen plates move upward to meet the descending clay. The fine particles drop through the perforations in the plates, while the larger particles pass off the end of screen below. The plates are kept clean by a metallic brush-roller which is attached to the lower side of the screen, and removes the clay from the plates as they are brought beneath the frame.

Eleven plants in Mississippi, out of a total of 65 reporting, use some form of screen.

TEMPERING.

Clays are tempered either by the use of soak pit, ring pit, pug mills, wet pans or chasers.

Soak Pit.—The soak pit is employed in some soft mud plants. The pit consists of an excavation of rectangular area, into which the clay is thrown. Some pits have bare walls, others are provided with plank walls and bottom. In some plants four or five of these pits are located along a line in front of the drying shed or yard and the molding machine, which is placed upon trucks, is moved from pit to pit as the clay in one pit is exhausted. The time required for soaking depends on the texture, and the slaking power of the clay. The clay is usually allowed to remain in the pit at least twelve hours. In case it is to be used for hand molding, it is first "slashed out" with a spade, a process of mixing by hand power. If the clay is to be used in machine molding, it is thrown into the box of the machine where it is pugged before delivery to the molds. The clay and whatever non-plastic material, such as sand or sandy clay, is necessary, is placed in the pit and then wet down by water conducted to the pit by pipes from barrels, wells or reservoirs. There are not many soak pits used by Mississippi brick plants. Out of 65 plants, only 6 use the soak pit.

Ring Pit.—Ring pits are of two types, viz.; those operated by horse power and those operated by steam power. They are similar in form and general make, but differ in size and capacity. They vary in capacity from 8,000 to 30,000 bricks. The pit is circular in area and from 2 to 3 feet in depth. The mixer consists of a beam bearing a wheel, the former being attached at one end to a pivotal stake set in the center of the pit. The wheel, which is constructed of iron, has a diameter of about six feet. As the sweep is moved round the ring, the wheel revolves on the beam as an axis, and at the same time moves either outward to the periphery or inward toward the center of the pit, the direction being determined by its position at the start. By means of this alternating centripetal and centrifugal motion, every portion of the pit is traversed by the wheel and the clay thoroughly mixed.

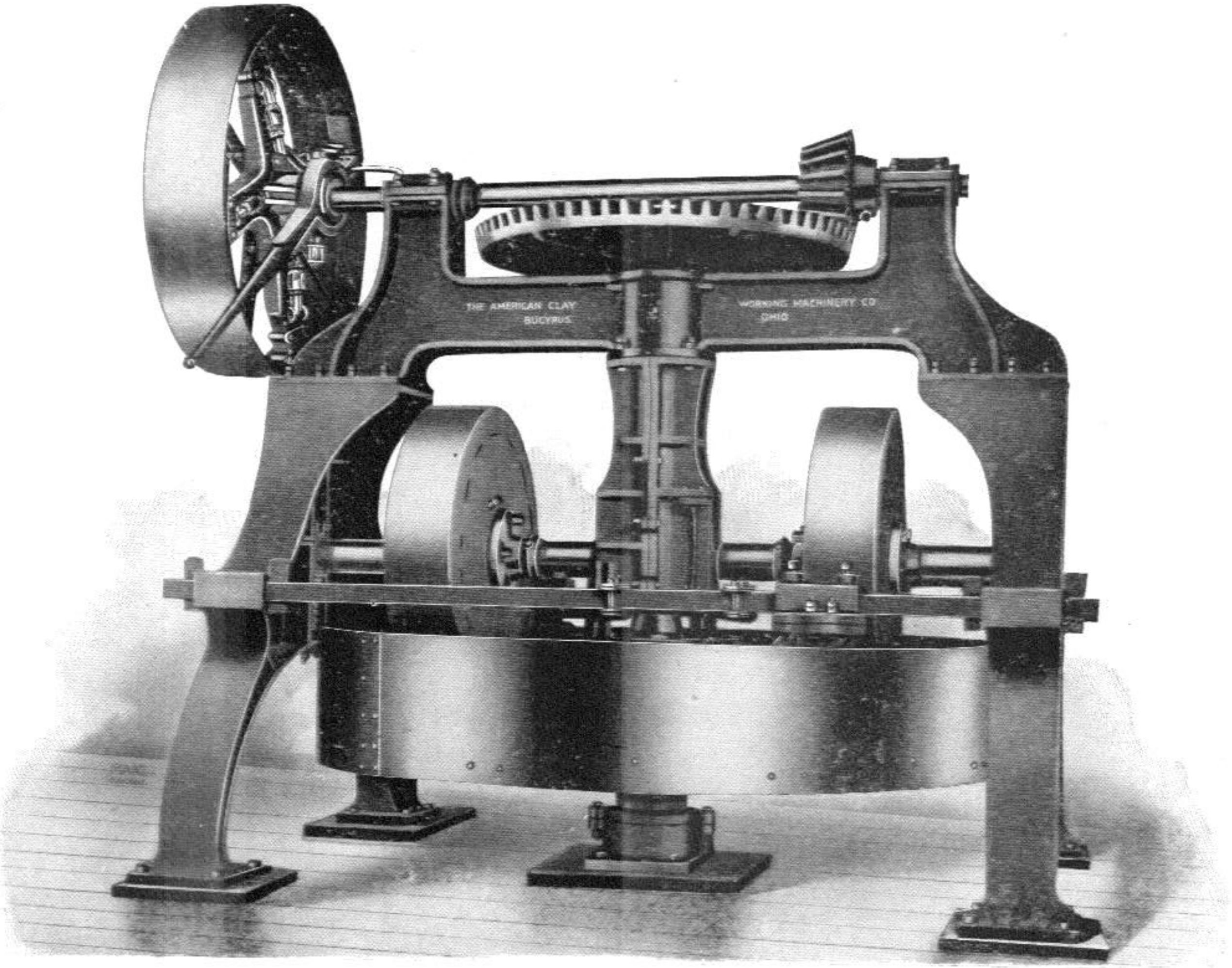
The small size pit having a capacity of 8,000 bricks requires a two-horse team for operation. The time required for tempering in the ring pit varies with the clay used. The residual loess clays may be tempered in from two to three hours. These clays, however, slack very readily. With some clays it is necessary to use ring pits, so that the clay which is being tempered one day can be used by the molders the day following.

There are 9 plants out of 65 reporting which use the ring pit. These are all operated by horse power.

Pug Mill.—Pug mills are also used for tempering clay. Nearly every brick machine of soft-mud or stiff-mud type contains some provision for mixing the clay. In the soft-mud machine of the vertical type, the clay is pugged in the upper part of the machine, and then forced below into the molds. In the steam-power soft-mud machine a separate pug mill is employed. This consists of a semi-cylindrical chamber, open at the top, in which a horizontal shaft revolves. The shaft is provided with blades which cut up the clay, and mix it thoroughly. The clay enters the chamber at one end, is softened with water, and forced by the revolving blades toward the opposite end of the pug mill, where it is discharged into the molding chamber. The angle at which the blades are set on the shaft determines the speed at which the clay is discharged. For thorough mixing and high speed, the pug mill should be long, so that the clay may come in contact with a large number of blades. Ordinarily pug mills vary in length from 5 to 10 feet. (See Plates XIII and XV.)

In stiff-mud machines, sometimes only short pugging chambers are in direct connection with the molding chamber, and the clays are

PLATE XIV.



WET PAN.

tempered and forced through the die by the revolutions of the same shaft. For the majority of clays in use in this State, this form of tempering is not advisable if the pugging is the only form of preparation given the clay before molding. In many plants the pug mill is the only crushing machinery used. It is expected not only to disintegrate the clay but to mix it as well. This cannot be accomplished in a small pug mill.

Wet Pan.—Wet pans are circular pans in which a pair of heavy iron wheels travel. The clay is placed in the pan, softened with water, and crushed and mixed by the movement of the wheels between the bottom of the pan and the surface of the wheels. Wet pans are not commonly employed in brick plants. They may be employed to advantage in potteries or fire-brick plants. (See Plate XIV.)

The "chaser" used in some potteries consists of a wooden or iron wheel which revolves in a circular path on a floor and crushes and mixes the clay.

TABLE 16.

SUMMARY OF TEMPERING MACHINERY USED IN MISSISSIPPI BRICK PLANTS.

Number of yards using soak pits	6
" " " " ring pits	9
" " " " separate pug mills	17
" " " " wet pans	0
" " " " chasers	0
" " " " no separate tempering machinery	33
Total number of yards reporting	65

MOLDING.

Clay which is molded into brick may be used as a soft mud, a stiff mud, as dry or semi-dry clay. The methods of molding clays into brick may be classed according to the following grouping:

- Soft-mud process.
  - Hand molding.
  - Machine molding.
    - Horse power.
    - Steam power.
- Stiff-mud process.
  - Plunger type machine.
  - Auger type machine.
- Repressing brick.
- Dry press process.
  - Hydraulic power.
  - Steam power.

In some plants two or more methods of molding are employed. They may manufacture soft-mud brick, stiff-mud brick and dry-pressed brick. Very few clays are adapted to all methods of manufacture. A sandy type of clay is better adapted to the soft-mud process. A more plastic clay can be used to better advantage in a stiff-mud machine. It is possible in many clay pits to secure a variety of clays, so that mixtures may be made which will permit the use of all three methods of molding.

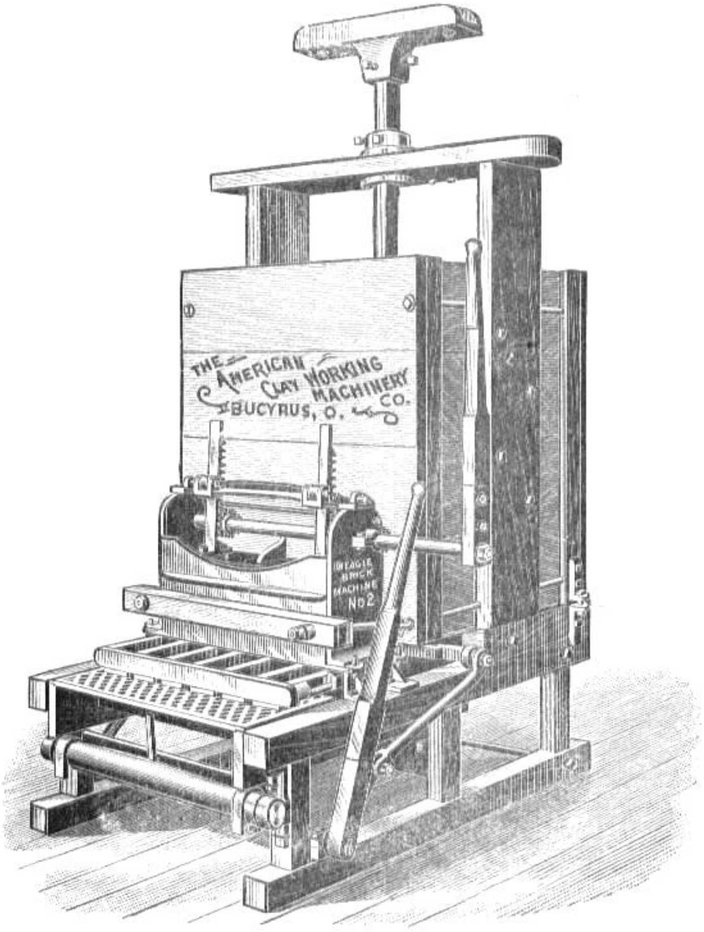
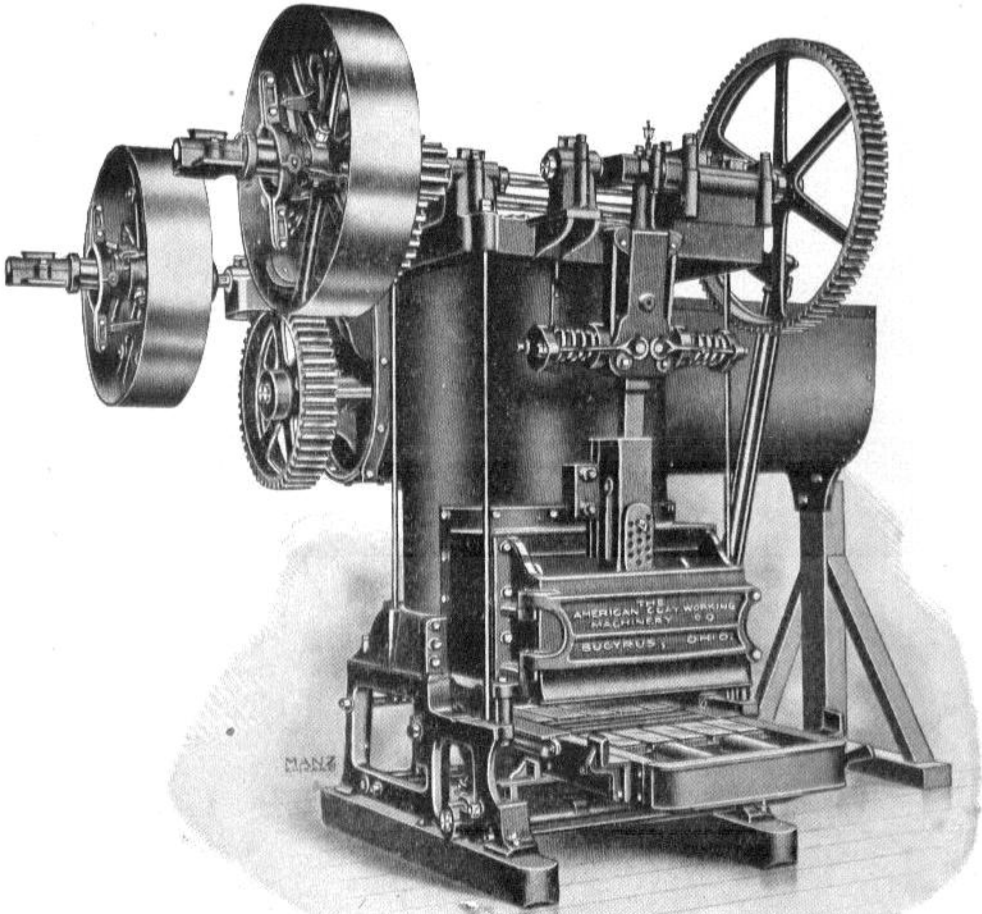


FIGURE 7. HORSE-POWER SOFT-MUD BRICK MACHINE.

PLATE XV.



SOFT-MUD BRICK MACHINE AND PUG MILL.

Soft-mud Process.

Hand Molding.—The tempered clay is taken from the soak pit or the ring pit and loaded on a wheelbarrow by the use of a spade. The wheelbarrow is then run to the molding table, which usually stands on the drying floor. The drying floor is a level and smooth tract of land which is covered with a thin coating of sand. The molding table is now sprinkled with water and then with sand, and the clay transferred from the wheelbarrow to the table. The off-bearer takes a molding frame which contains six molds, and dipping it first in water and then in sand, places it on the table in front of the molder. The molder takes a mass of clay, rolls it, and kneads it. He then drives it by a sudden downward stroke into a mold. This is repeated until the six molds are filled. The clay is stroked from the top of the mold by the use of a wire stretched between the points of a bow. The surplus clay cut from the top of the molds is called "caps," and is thrown back on the table to be used again.

The off-bearer takes the molding frames and empties them upon the drying floor. After drying for a few hours the bricks are turned upon edge, a process called edging. After remaining upon the drying floor from twelve to twenty-four hours the bricks are laid in loose piles, a process called "hacking." Hacking the output of the preceding day allows the use of the same drying floor for the new day's run. Then it makes it possible better to protect the brick from rain, because of the limited space which they now occupy. When they are piled up canvas or boards may be used to cover them.

In some yards the molding tables are moved along between racks in which the brick are placed upon pallets. As soon as the sections on each side of the table are filled with brick-loaded pallets the table is moved to the next section. One man can mold 8,000 bricks in a day of ten hours, but in most plants from 5,000 to 6,000 is considered a day's work. In one plant one man molds and places in the rack 6,000 bricks, for which he receives $1.50 per day.

Machine Molding.—According to the power used molding machines may be classed as horse-power machines and steam-power machines. The horse-power machine consists of an upright rectangular box in which a vertical shaft supplied with arms turns by means of a sweep. The sweep is attached to the shaft near the larger

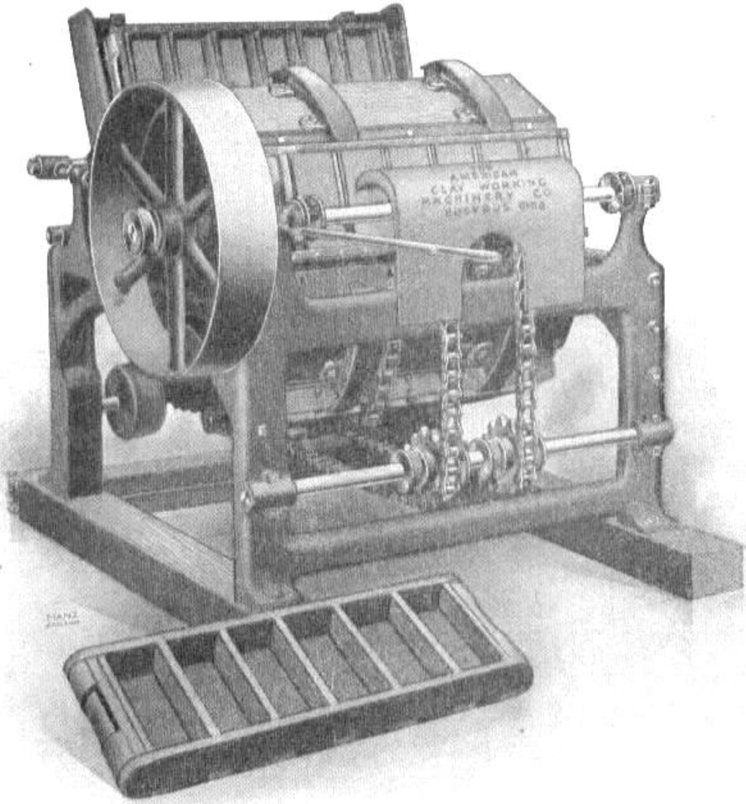


FIGURE 8. BRICK MOLD SANDING MACHINE.

end of the former, the projecting heavy end of the sweep being used as a counterpoise. The horses are hitched to the small end of the sweep and travel in a circular path around the machine.

The clay is thrown into the opening at the top of the machine, and after being thoroughly mixed or pugged by the arms in the upper part of the box, is worked to the bottom and pressed by plungers located near the bottom of the shaft into the molds. The molds are generally held in wooden frames, there being six molds to a frame. The molds are passed under the machine at one side, become filled from the press box and are taken out on the other. By moving a lever the filled frame is thrown out and an empty one inserted beneath the press box. They may not be completely stroked as they leave the machine, so that it may be necessary to use a wire or paddle to remove remaining clay. The molds are first dampened and then sanded. The use of the sand is to prevent the clay from sticking to the molds. The more plastic the clay the more tenaciously it clings to the molds. The molds may be sanded by shoveling sand into the molds, shaking it about and then tossing it out.

The mold-sander is a machine constructed for the purpose of saving labor in sanding molds. It consists of a frame which rotates in a cylinder. The molds are placed in the frame, and by the rotation of the latter the molds are forced through a bed of sand in the bottom of the cylinder.

Some of the soft-mud horse-power machines are placed upon low trucks and moved from soak pit to soak pit as the clay is used. Machines of the horse-power type have a capacity of from 8,000 to 15,000 bricks per day of ten hours. Soft-mud machines of steam power have a capacity ranging from 18,000 to 35,000 bricks per day. For a machine of the latter capacity five men and three boys are required at the machine. Three off-bearers are required if no car system is used; if a car system is used one off-bearer can handle the output of the machine.

Indurated clays and clays of high plasticity cannot be used with economy in the soft-mud process. In this State only the sandy type of surface clays is used. The residual clay covering the loess is molded in a large number of plants by the soft-mud process. The Selma residual is not generally successfully used in the soft-mud process unless there is considerable sandy clay present for mixing.

There are sometimes nearby deposits of Lafayette which may be used for tempering the clay. The alluvial clays of the Yazoo basin have been used for the manufacture of soft-mud brick. The sandy type of clays is best adapted to the soft-mud process. The "buckshot" clays adhere to the mold, shrink excessively and are difficult to pug.

Stiff-mud Process.

The machines used in the stiff-mud process of molding are of two types, a vertical machine, in which the clays are pressed into the molds by the action of plungers, and an auger machine, which may be either vertical or horizontal.

Plunger Type Machine.—The plunger machine is provided with a revolving wheel which contains the molds. As the wheel revolves clay is pressed into some of the molds by descending plungers, then as the plungers are lifted, the bottom of the mold rises and forces the molded brick out. Thus a portion of the wheel passes under the machine and a portion is in the open and forms the delivery table. The pugging chamber is usually directly above the molds. Just enough water is added to the clay to form a stiff mud. The molded brick are in a condition to permit handling without danger of much loss, whereas a soft-mud brick would first require a certain amount of drying.

Auger Type Machine.—In the vertical auger type machine the clay is forced by an auger to the base of the machine. From this point the clay is forced through a rectangular die. The size of this die may be either the same size as the cross section of a brick or the same size as a horizontal section. The clay which is forced through the die forms a bar of clay which is usually strong enough to retain its shape under considerable strain. After the clay is tempered it is placed in the small pugging chamber in which there turns a vertical shaft. At the top this shaft is provided with small blades for pugging the clay. The lower part of the shaft is provided with an auger, which catches the clay forced downward by the pugging blades, and presses it through the die. The friction of the bar of clay against the die may cause the edges of the bar to break and curl, forming serrations. The clay may lack cohesive power, in which case more bonding material should be added.

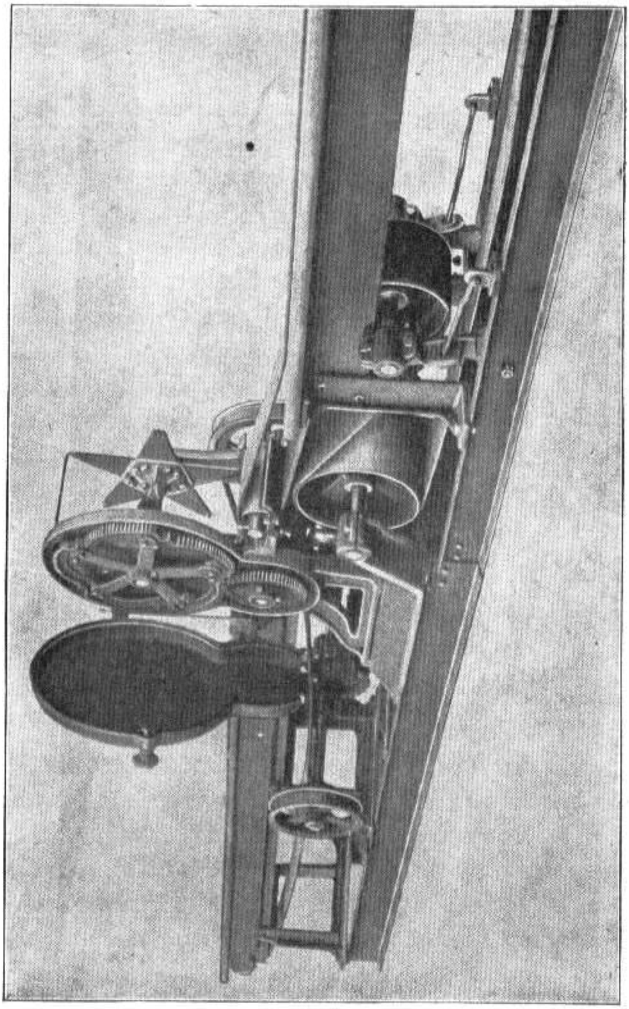


FIGURE 9. AUTOMATIC CONTINUOUS ROTARY BRICK CUTTER.

Various substances are employed to decrease the amount of friction between the steel die and the clay bar. Steam under high pressure may be forced in around the bar in the die. Kerosene or lubricating oil is often employed as a lubricant in some plants and soap suds in others. The surface of the bar is sometimes coated with sand as it leaves the die, to facilitate handling and hacking without injury.

The spiral motion of the auger, the friction of the clay against the surface of the auger, producing smooth clay surfaces, and the differential velocities in the bar of clay produced by friction of the die, all cause laminations in the clay.

In the horizontal auger type of stiff-mud machine a horizontal shaft works in a cylindrical pugging chamber, and supports at the end opposite the die short blades which pug the clay and force it to the auger, by which it is in turn forced through the die.

In the multiple-bar type there are two or more dies through which the clay is forced, thus forming as many parallel bars of clay.

As the clay issues from the die it is carried by a belt across the cutting table, where it is cut into bricks. The cutters are either "side-cut" or "end-cut." Where the side-cut is employed the width of the bar is the length of the brick, and where the end-cut is employed the width of the bar is the width of the brick.

The cut surface of the brick in the former is on the side of the brick, in the latter on the end of the brick. Side-cut brick dry more rapidly than end-cut brick, because of the greater area of cut surface which is more porous than the die-puddled surface.

Some cutters are operated by hand, others are automatic. There are two automatic side cutters in general use. One is the rotary, consisting of a wheel provided with wire spokes. By the rotation of the wheel these wires are passed through the bar of clay at regular intervals, the movement of the bar being co-ordinated with the rotation of the wheel. The other side cutter is the oscillating, reciprocal cutter, which consists of a frame between the projecting points of which wires are stretched. The wires are separated by the thickness of a brick. These wires, by a lateral or downward movement, are forced through the bar. During the time of cutting the bar is moving forward and the cutter has a reciprocal movement.

The end cutter consists of a revolving wheel, the spokes of which are bifurcate near the ends, having wires stretched between the points of the bifurcations. As the wheel revolves the wires are forced through the bar of clay cutting it into brick lengths.

As the bricks leave the cutter they are caught by the off-bearing belt, which moves at a greater velocity than the bar of clay, and soon separates the brick. The brick are taken from the off-bearing belt and placed upon cars or pallets for transportation to the dryer.

Repressing Brick.

Stiff-mud brick or soft-mud brick after molding are often pressed in a machine called the "repress." The repress consists of a steel mold box into which the brick are placed and subjected to strong pressure. The hand repress (see Fig. 10) consists of a heavy iron frame supporting a steel mold box, which is provided with a removable top and a movable bottom plate, which is forced upward against the brick in the mold. The pressure exerted by the movable bottom (plunger) is obtained by throwing back the lever. When the top is removed and the lever thrown back, the repressed brick is forced to the top of the mold. These represses have a weight of from 700 to 900 pounds and a capacity of from 2,000 to 3,000 brick per day.

The larger represses are operated by steam (see Plate XVIII). They generally have two molds and have a capacity of from 10,000 to 25,000 brick per day. They vary in weight from 5,000 to 9,000 pounds and exert a pressure of 4,000 or 5,000 pounds per square inch. The pressure may be applied by plungers from above or by plungers both above and below.

The brick from a stiff-mud machine may be taken immediately to the repress. Soft-mud brick must dry to about the consistency of stiff-mud brick before repressing. There is an advantage to be gained in allowing stiff-mud brick to dry a little before repressing, as in that case defects of drying may be partly obliterated.

The principal things to be gained by repressing are: (1) An increase in the density of the brick. The clay particles are brought closer together and their union is more perfect. This diminishes the porosity of the brick and decreases its absorption power. (2) A partial destruction of laminations and serrations. Stiff-mud brick

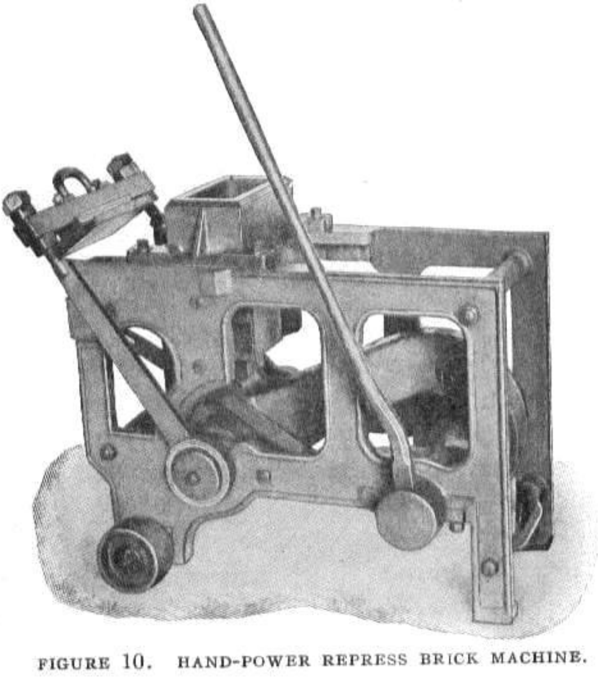


FIGURE 10. HAND-POWER REPRESS BRICK MACHINE.

are often serrated on the edges. The auger also produces a laminated structure. Both of these structures may be at least partly obliterated by repressing. (3) The surfaces of wire cut brick are often rough. This roughness may be destroyed and the surface of the brick made smooth by repressing. (4) The form of the brick may be improved by repressing and its strength increased. The edges of the brick which may have been rounded in the die are shaped. Indentations are removed. (5) Any desired name, design or mark may be imprinted on the surface of the brick.

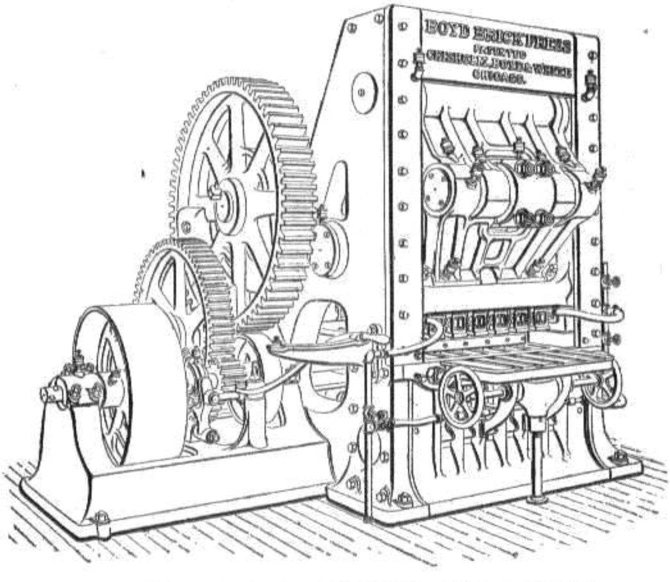


FIGURE 11. SIX-MOLD DRY-PRESS BRICK MACHINE.

Dry-press Process.

In the dry-press process the clay is first reduced to a powder in a disintegrator or pulverizer. It is then screened to remove all particles larger than one-sixteenth of an inch in diameter. The air-dried clay is then pressed into molds with a pressure sufficient to cause the particles to adhere so firmly that the brick may undergo without crumbling all of the handling that raw clay brick usually have to endure. The dry-press machine (see Figure 11) consists of a heavy steel frame containing a press box and a delivery table. The molds (usually four to six) are filled with clay by a charger which is connected with the clay hopper by a canvas tube. When filled with clay the charger glides forward over the molds, filling them with clay. Then as the charger returns to be refilled the plunger descends and forces the clay into the mold. At the same time the bottom of the molds are pressed upward and thus the clay is subjected to two pressure movements. As the plunger rises the bottom of the molds continues to come up, thus forcing the brick out of the molds to a level with the surface of the delivery table upon which they are pushed by the next forward movement of the charger. The surfaces of the molds are heated by steam in order to prevent the clay from sticking. To prevent the imprisonment of air in the brick, holes are made in the press plates to allow its escape.

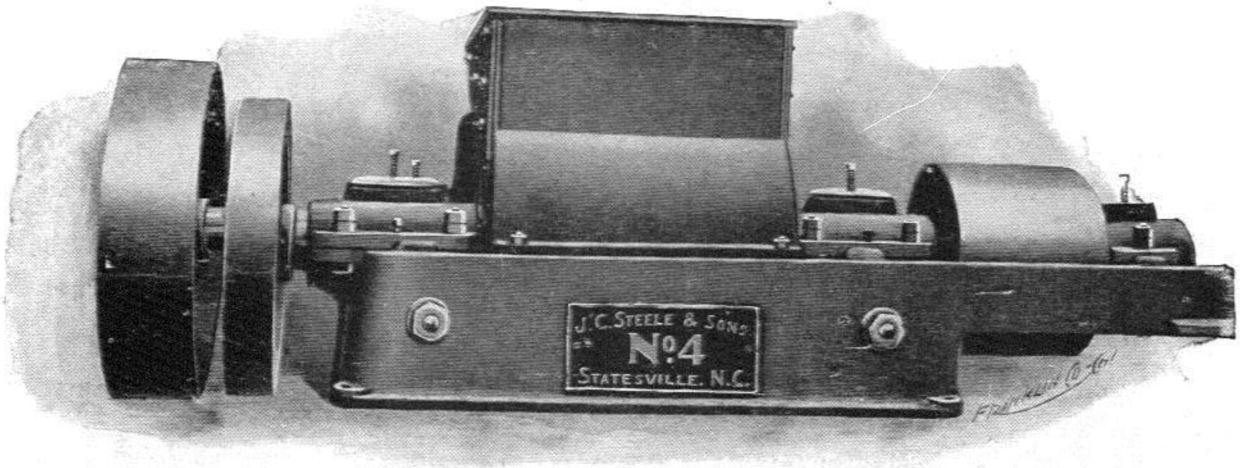
The clay used by the dry-press machine is generally placed in a storage shed and allowed to mellow for a few weeks, or in some plants months before it is used. Under the mellowing process capillary moisture becomes more thoroughly distributed, the clay lumps are softened and the reduction to the powdered state rendered easier. In case two or more kinds of clay are used, the mixing may be done thoroughly by placing them in the storing shed in successive layers. In using the clay a vertical section of the deposit is taken. Storing a large quantity of clay in the shed during favorable weather makes it possible for the plant to continue operations during unfavorable weather periods. The dry pressed brick may be taken directly from the press and placed in the kiln. The expense of drying is avoided. Because, however, of the density of the brick the water-smoking period is longer than in the soft-mud or the stiff-mud brick.

TABLE 17,

METHODS OF MOLDING MISSISSIPPI BRICK.

1. By soft mud process.	
a. Number of plants using hand power	11
b. " " " " horse power	2
c. " " " " steam power	7
2. By stiff mud process.	
a. Auger type, end cut, single die	19
b. " " " " double die	2
c. " " side cut, single die	6
d. Plunger, vertical type	7
3. By dry-press process	11
Total	65

PLATE XVI.



CLAY DISINTEGRATOR.

DRYING.

When brick are brought from the molding machine they contain the water necessary for tempering the clay. Before they can be burned this water must be removed. It must be removed so gradually as not to impair the strength or appearance of the brick. This process of water removal is called drying. In the following pages are presented some of the fundamental facts upon which the removal of water from clay is dependent.

Principles of Drying.

Humidity is the condition of the atmosphere with respect to its water-vapor content. The total amount of moisture that the air is capable of containing at any given temperature constitutes the capacity of the air at that temperature. The capacity of the air varies with the temperature. The air is said to be saturated when the amount of water vapor which it contains is equal to its capacity. The amount of moisture actually present in the atmosphere is termed its absolute humidity. The relative humidity is the ratio of the absolute humidity to the capacity of the atmosphere. For example, air at a temperature of 50° F. has a capacity of 4 grains per cubic foot. Suppose, however, the air at this temperature contained but 2 grains of moisture per cubic foot. The absolute humidity of the air is 2 grains per cubic foot and its relative humidity is the ratio which 2 grains (absolute humidity) bears to 4 grains (capacity), which is one-half or 50 per cent. Air which has a relative humidity as high as 80 per cent is considered moist air. If the relative humidity is below 50 per cent the air is called dry air, and its humidity is low.

The capacity of the air depends upon its temperature. The higher the temperature of the air the more moisture it can contain. Air at a low temperature might be considered damp though it contains just the same amount of moisture as air which, at a higher temperature, would be considered dry.

For example, air at 50° F. has a capacity of 4 grains per cubic foot. Now, if the air at that temperature contained 3 grains per cubic foot it would be considered moist air, since its relative humidity is 75 per cent. Now let the same air be raised to a temperature of 100° F., and it now has the capacity of approximately 20 grains.

But the relative humidity is now only 15 per cent, and it is an exceedingly dry air.

Water is lost from a wet body by evaporation. Evaporation is the transfer of moisture from one area to a less humid area. Such transference does not take place between two saturated bodies, but between a saturated body and a non-saturated body. Water may pass from a wet surface to the surrounding air, provided the air is not saturated. Evaporation is produced through the vibration of molecules, which causes some of those at the surface to fly off into space. The vibration of the molecules is produced by heat, and the higher the temperature of the water the more rapidly the molecules separate. Evaporation takes place from the surface of ice, but it takes place much more rapidly from the surface of water at the boiling point. At this point the vapor tension is equal to the pressure of the atmosphere which it will displace.

At the point of evaporation water assumes the form of a gas, and expands to 1,700 times its liquid volume. When the surrounding air contains all of the vapor it can hold it is saturated. The point of saturation depends on the temperature of the vapor.

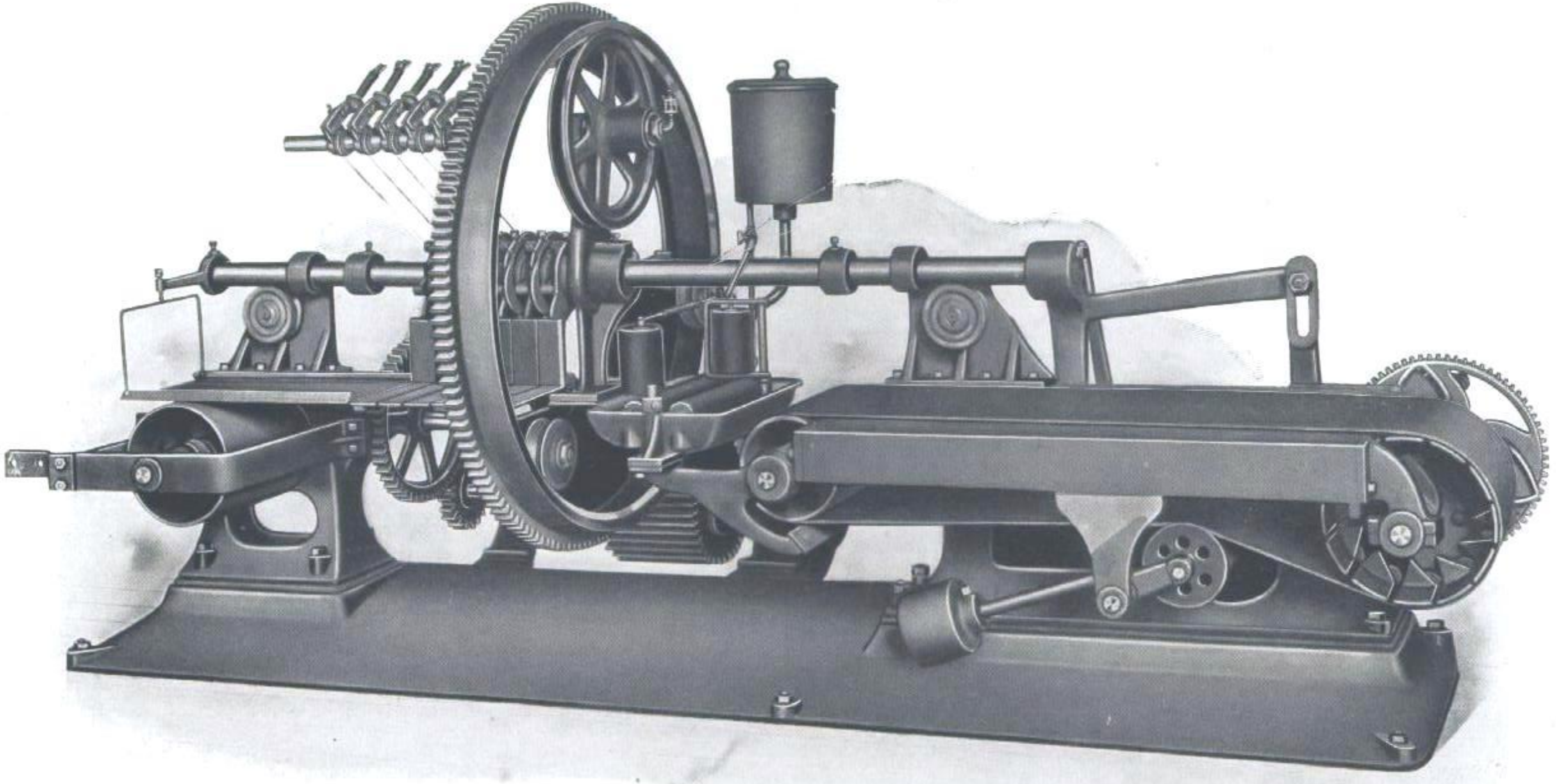
TABLE 18.

NUMBER OF GRAINS OF SATURATED WATER VAPOR IN A CUBIC FOOT AT VARIOUS TEMPERATURES.

10°	.776	34°	2.279	58°	5.370	82°	11.626
12°	.856	36°	2.457	60°	5.745	84°	12.356
14°	.941	38°	2.646	62°	6.142	86°	13.127
16°	1.032	40°	2.849	64°	6.563	88°	13.937
18°	1.128	42°	3.064	66°	7.009	90°	14.790
20°	1.235	44°	3.294	68°	7.480	92°	15.689
22°	1.355	46°	3.539	70°	7.980	94°	16.634
24°	1.483	48°	3.800	72°	8.508	96°	17.626
26°	1.623	50°	4.076	74°	9.066	98°	18.671
28°	1.773	52°	4.372	76°	9.655	100°	19.766
30°	1.935	54°	4.685	78°	10.277	102°	20.917
32°	2.113	56°	5.016	80°	10.934	104°	22.125

Water evaporates more rapidly into a vacuum than into space filled with air, but at a given temperature the same quantity of water will evaporate into each. A mixture of air and water vapor has a greater expansive power than air alone. If to a cubic foot of dry air weighing 516 grains at a temperature of 80° F., 11 grains of water vapor be added by evaporation, the whole mixture will weigh but 510 grains. Then its density is less than the original air.

PLATE XVII.



ROTARY AUTOMATIC BRICK CUTTER.

Brick are dried by evaporation of water which they contain. When taken from the mold, brick contains water in two forms, viz., the water which has been added for tempering, and hygroscopic moisture. The former passes readily from the clay at ordinary temperature; the latter can only be expelled at the temperature of boiling water. It is the water which is absorbed from the atmosphere, and is present in all clays except those kept in absolutely dry air, and is the water which is removed from brick in the process of water-smoking.

The object to be obtained in drying brick is the economical and rapid removal of water without impairing in any way the quality of the brick. The tenacity with which moisture is held by clays varies. As a rule the finer the grain of the clay constituents, the more slowly it gives up its water. Since clay is as a rule finer in grain than sand, the higher the amount of clay the greater the difficulty of drying. Since plasticity is affected by these conditions, the higher the degree of plasticity the more difficulty encountered in drying. A very sandy clay will dry rapidly, but it may be weak because of the small amount of bonding material. When the brick are taken from the machine, they have the same temperature as the surrounding atmosphere. If they are put in a dryer which has a higher temperature, they begin to lose moisture rapidly as the temperature of the dryer is raised. But since clay absorbes heat slowly, if the temperature of the dryer is too high, the outside of the brick may become dry before the inside becomes hot. This produces differential shrinkage, the outside of the brick contracting more than the inside. The results of such differential contraction is the cracking or checking of the brick. The more plastic the clay, the more care must be exercised in drying. The remedy lies in the very gradual increase in the temperature of the brick.

In many of the steam dryers now in use, a "dead chamber" is used for heating the brick to the temperature of the first chamber of the dryer. The "dead chamber" is a closed division of the dryer into which steam is turned, there being no means of circulation, or at least very little. The brick do not dry, but become heated thoroughly by the steam. When they reach the temperature of the air at the beginning of the dryer, they are run into the first chamber of the dryer, and are then in a condition to pass through the dryer rapidly.

Since air is the medium through which the water is removed from brick, the drier the air used the greater its drying capacity. The air used in an artificial dryer must be taken from the atmosphere, therefore, the amount of moisture that enters a dryer on a given day will depend on the humidity of the atmosphere. Beyer and Williams* make a calculation of the amount of heat necessary to evaporate the water contained in 1,000 brick. The subject is treated as follows: "Clays vary a great deal in the quantity of water required for tempering. Since tempering water only is removed in the dryer, the amount which it is necessary to evaporate in drying also varies. As an average, it may be said that clays worked by the plastic process contain 22 per cent of water. For one thousand brick, this means in the neighborhood of 1,700 pounds of water to evaporate in drying. A dryer tunnel containing twelve cars each loaded with five hundred standard bricks must pass enough air to carry out over five tons of water from these brick. It thus becomes a problem for investigation to determine for a given dryer the most saving conditions under which this water can be removed.

"In open air drying, the currents of air which carry away the water are warmed by the sun's heat. The specific heat of air is .2374. A cubic meter (1.308 cu. yds.) of air weighs 1.293 kilograms at O°C. and 760 mm. barometric pressure. The heat contents of each cubic meter of air at zero degrees is, therefore, 1.293 times .237 = .306 kilogram calories. At any higher degree, its contained heat would be, $\frac{1.293 \text{ times } .237 \text{ times } t}{1 + a t}$, in which a is the coefficient of expansion = .00367 and t the observed temperature. If we assume an average summer heat of 16 C. (most out of door drying being done in the summer), it is seen by the formula that the heat content of a cubic meter of air is 4.631 units, which shows an average of essentially .3 heat units for each degree of temperature. These heat units are taken up as latent heat by the water in drying and as a consequence the temperature of the air is lowered. This means that for every degree the air is cooled, it loses .3 of a unit of heat. The measurable heat of water and the latent heat of water vapor formed at ordinary temperatures may be taken as 611 heat units, *i. e.*, to evaporate one kilogram of water at 16 C. requires 611 heat units; .3 units, therefore, $(\frac{3 \text{ times } 1{,}000 \text{ gms.}}{611})$ will evaporate at this temperature only .491 of a gram.

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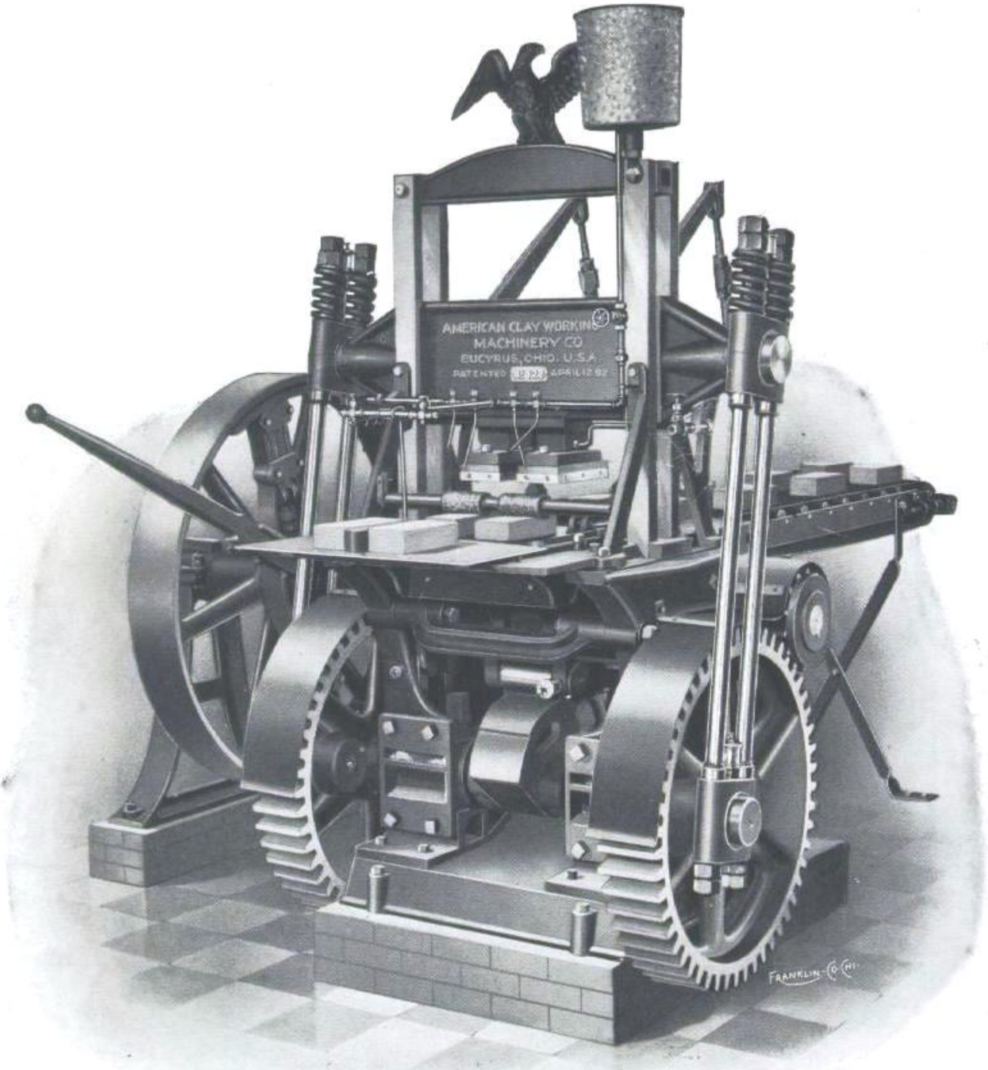
*Iowa Survey. Pages 239-243. Rept. for 1903.

PLATE XVIII.



STEAM-POWER DOUBLE-MOLD BRICK REPRESS.

"We have already assumed an average of 1,700 pounds (772+ kgms.) of water per thousand brick. To evaporate 772 kilograms of water requires 611 times 772=471,692 heat units. To dry a thousand brick, therefore, with air at ordinary temperature, requires that 1,572,301 (772,000÷.491) cubic meters of air lower one degree in temperature to furnish the required amount of energy. Or, where the air is somewhat confined as in drying sheds so that it may remain in contact with the wet ware for some time, the same evaporative power would be possessed by one-half the volume lowering two degrees, or by one-tenth lowering ten degrees and so on.

"Whether or not drying actually approaches in efficiency these theoretical figures depends largely on the humidity of the air. Air near its saturation point gives up its heat much less readily and will consequently take up water more slowly than comparatively dry air. Rapidity of movement of the currents of air also influence their drying capacity. As a general thing, very little change of temperature is ever actually noticed in outside drying, but the drying depends largely on the air circulation. The more rapidly this takes place, the more air is brought in contact with the clay and consequently drying progresses more speedily.

"In closed chamber dryers the conditions are different from those discussed in several particulars. The air no longer circulates of itself but a draft must be produced to move it. The heat for drying is not contained in the air as it enters from the outside, but must be supplied to it artificially. Both movement of the air and heating it requires the expenditure of energy which is not necessary in out of door drying. Of the heat supplied to the air, it is clear that not all is utilized in the evaporation of water; for this air leaves the dryer at a higher temperature than it enters, thus carrying out considerable quantities of sensible heat. Likewise, the brick enter the dryer at atmospheric temperatures and leave it at much higher temperatures. These are the chief sources of waste of heat in the dryer and are in turn briefly treated.

"On leaving a drying chamber, one cubic meter of vapor-saturated air at 30° C. consists of .958 cubic meter of dry air and .042 of water vapor $(\frac{760-31.6}{760})$, where 31.6 is the tension of aqueous vapor.

"The .958 cubic meter of dry air can hold the following heat units: $\frac{1.293 \times .958 \times .237 \times 30}{1 + .00367 \times 30} = 7.935$ heat units.

"When this same dry air entered the dryer at, say, 10° C., it had a volume of

$$\frac{958}{1+.00367(30-10)} = .893 \text{ cubic meters.}$$

"This volume of air could carry as it came into the dryer

$$\frac{1.293\times .893\times .237\times 10^\circ}{1+.00367\times 10} = 2.639 \text{ heat units.}$$

"The amount of heat taken out of the dryer, therefore, in each cubic meter of air under the assumed conditions is 7.935—2.639 =5.296 heat units.

"The above result is obtained on the assumption that the air on issuing from the dryer is completely saturated. This is seldom if ever true. Its degree of saturation or relative humidity may be ascertained in any instance and the value used in the formula. Assuming for example that the outgoing air is but half saturated, which is ordinarily more nearly the case, similar calculations to the above will show that at 30° C. 8,108 heat units will be carried out per cubic meter of saturated air. At 10° the same air carries in 2.696, making a loss in this case of 5.412 heat units. If each cubic meter passing through the dryer causes a loss of 5.412 units of heat, the total loss per each thousand brick is 56,610 heat units.

"In the same manner may be calculated the loss of heat incurred by bringing the air into, and removing it from, the dryer at any observed temperatures.

"We have seen that at these low temperatures 611 heat units are required for the evaporation of each kilogram of water. As has been shown, to remove the water from 1,000 brick (772 kgms.) requires 471,692 heat units. And since each cubic meter of air at the highest temperature, 30° C., can evaporate 13.55 grams of water, to dry 1,000 brick takes 772×13.55 or 10,460+cubic meters of air.

"Seger gives the following formulae for the calculation of the capacity of chimneys. In their practical application these expressions may be used for determining the dimensions of a stack for circulating an amount of air, at the temperatures of operation, which is found necessary to remove the water from a given amount of clay in the time required to dry it.

"$V = 628\sqrt{\frac{(t-t^1)\,dh}{4.08.+016h}}$ = velocity of air in meters per minute and,

"$V = \frac{3.1416d^2v}{4}$ = volume of air in cubic meters per minute.

FIGURE 12. STEEL RACK CAR FOR TRANSPORTING BRICK ON PALLETS.

"In these formulae:

"$t—t^1$ = the temperature difference between the shaft of the chimney and the outside air,

"d = the diameter of the chimney at its mouth,

"h = the height.

"The clay as it enters the drying chamber has the temperature of the atmosphere and as it leaves carries out considerable quantities of sensible heat. The specific heat of clay is about .2. The heat carried out is calculated by the weight of the ware, or, M, multiplied by .2 $(t—t^1)$ where $t—t^1$ = difference in temperature of the brick at entrance and exit. One thousand brick contain on an average 7,700 pounds, 3,500 kilograms, of dry clay. Under the conditions assumed above, 3,500 × .2 (30—10) 14,000 heat units per thousand brick.

"We have now obtained the amount of heat used in the evaporation of water from 1,000 brick, 471,692 heat units; that taken out as sensible heat in the escaping half-saturated air, 56,110, and the heat dissipated by the clay itself, 14,000 heat units. Total energy necessary to dry 1,000 brick, neglecting radiation, is, therefore, 542,302 units of heat.

"This energy is supplied in artificial dryers by the combustion of fuel. The average Iowa coal furnishes 6,700 heat units per kilogram. To dry a thousand brick requires the consumption, therefore, of, in round numbers, 81 kilograms, or 178 pounds of coal.

"By carrying out similar calculations to the above for a range of temperatures and different degrees of humidity, it may be shown that (1) economy can never be obtained unless the air is removed very nearly saturated. The rule in this regard is, therefore, to remove the air only after it has taken up practically all the water vapor it can hold, and before dew is deposited. (2) Economical drying in closed compartments can be had only at temperatures above 50° C. (122° F.), and below 100° C. (212° F.), when the air is removed as nearly saturated as possible. The amount of heat carried out by the air rises rapidly as the humidity decreases; and as the temperature of drying is lowered the ratio of heat loss to that actually used in the evaporation of water increases rapidly."

Methods of Drying Brick.

Brick dryers may be classed as open air dryers, and artificial dryers. The former may be further subdivided into (*a*) open yard dryers, (*b*) rack and pallet dryers, and (*c*) shed and hack dryers. The latter may be classed as (*a*) hot floor dryers, (*b*) chamber dryers, and (*c*) continuous tunnel dryers.

Open Yard Dryer.—This system of drying is used in soft-mud plants. The brick are placed on pallets from the mold. The loaded pallets are taken by the off-bearer to a sanded, open yard where they are emptied by inverting them. After drying a little, the brick are placed on edge to allow both sides of the brick to dry equally, and to prevent cracking of the upper surface due to unequal drying. After drying from 12 to 24 hours, the brick are hacked on the yard until the air drying is complete. The hacking makes it possible to handle a larger number of brick per yard, and at the same time makes it possible to more easily protect the brick in case of rain. The principal objections to this system of drying arise from the great amount of labor required to handle the brick, and the high per cent of loss sustained in inclement weather. The source of energy for the evaporation of the water is from the sun. There is no means of controlling the form of energy in the open yard. And it is impossible to control the circulation of the air and thus check the removal of moisture.

Rack and Pallet Dryer.—This system is used for both soft-mud and stiff-mud brick. The racks are covered with A-shaped roofs and generally open at the sides and the ends. Some, however, are provided with temporary walls consisting of movable plank, canvas, or burlap. Soft-mud brick are placed on pallets. Each pallet holds one mold full of brick, usually six. Where the brick are molded by hand, it is the practice to move the molding table along between the racks, filling them section by section.

Where a machine is used for molding, the brick are carried by hand, wheelbarrow or car to the racks. In some yards a rack car is used, and the loaded pallets are transferred from the car to the racks by an elevating movement of the car.

Usually in stiff-mud plants, the brick are packed upon large pallets as they are taken from the table. The pallets contain from

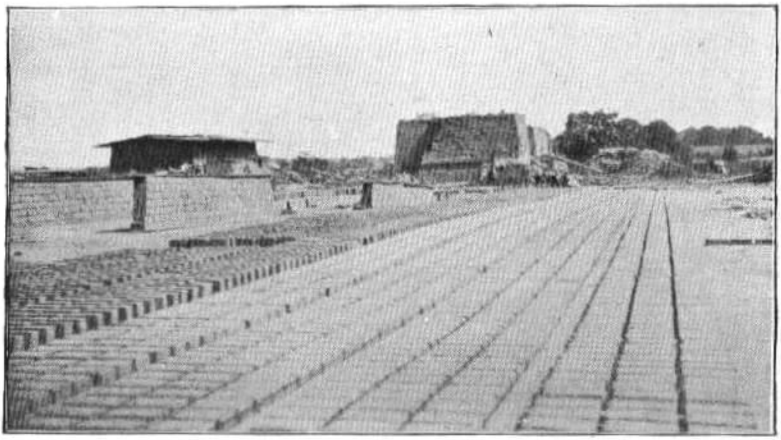
200 to 500 bricks. These pallets are transferred by elevating cars to racks or to sheds as the case may be. Considerable loss may be experienced in case no protection is provided for the racks in the way of side walls. Dashing rains may beat upon the brick. Currents of air may cause cracks by too rapid extraction of moisture from the exposed sides of the brick. The length of time required for drying is dependent on the conditions of the weather. In a dry atmosphere the brick may dry in a few days, whereas under humid conditions it may require weeks.

Shed Dryer.—Some plants are provided with large sheds with low supports or racks made in rows with car tracks between for the purpose of receiving the pallets with the hacked brick. In others no supports are used; the pallets are placed upon the floor or the brick hacked upon the floor without pallets. The brick are criss-crossed so that there is free circulation of air between them. The percentage of outside exposed brick is less than in the use of the rack and pallet and consequently the per cent of loss is less. The protection from storms is more efficient in the use of sheds. The cost of construction, however, is somewhat higher for the sheds. As in the case of the open yard, the source of energy for evaporation is from the sun for these last two mentioned dryers. The air currents, however, can be controlled. There is not the necessity of economizing in the volume of air that becomes imperative in the use of the steam or hot air dryer.

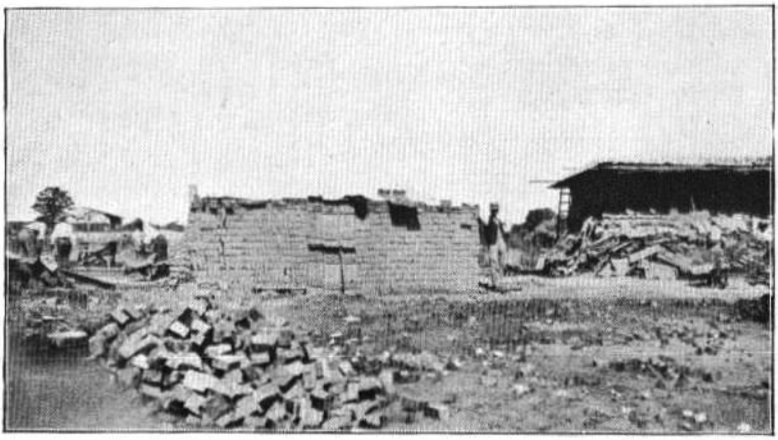
Artificial Dryers.—There are numerous forms of dryers which utilize either directly or indirectly heat derived from the combustion of fuel. Some of these dryers consist of a brick or metal floor under which fires are built. The clay ware to be dried is placed on the heated floor. In other floor dryers the floors consist of wooden strips which are heated by means of steam coils placed beneath the floor. This last form of dryer is commonly used for drying sewer pipe, drain tile, hollow blocks and terra cotta.

For drying brick two types of artificial dryers are in common use, the chamber dryer and the continuous tunnel dryer. The former consists of one or more rooms or chambers into which the brick are placed. Commonly the brick are hacked upon cars and the cars run into the dryer. The heat is furnished from steam pipes

PLATE XIX.



A. OPEN YARD SYSTEM OF DRYING, HOLLY SPRINGS.



B. HAND MOLDING AND STARTING A SCOVE KILN, HOLLY SPRINGS.

laid beneath the track. In some dryers pipes are also placed along the side walls or even along the roof. Under the track is considered the most advantageous position for the pipes. As the air in the chamber becomes heated it expands, rises and takes up moisture from the moist brick. The moist air is taken out through one or more chimneys or through a large wooden stack. The air is conducted from chamber to chamber by means of flues.

In the continuous tunnel dryer the heat supplied is increased as the distance from the entrance to the tunnel increases. The increase in heat may be obtained by increasing the number of sections of steam pipe. The brick are placed upon cars, which are run into the dryer from the stack end of the tunnel. They are gradually forced through the tunnel in the direction of increasing heat and decreasing moisture. The dried brick are taken out of the tunnel at the end opposite the stack.

Hot air used in drying brick may be obtained by utilizing the waste air in burning pottery or by heat produced in the burning of fuel. The air heated directly by the combustion of fuel is forced through the tunnel by means of a fan placed at the end opposite the dryer. The air heated by the furnace is drawn into a chamber where it loses its soot. After passing to the fan it is forced to the mixing chamber to be mixed with cold air. From the mixing chamber it is conducted to the dryer.

BURNING.

Burning is a term which is applied to that part of the process of brick manufacture during which the raw clay product is subjected to high temperatures. These high temperatures bake the clay. Hence the burning of brick is not at all analogous to the burning of wood or coal. The clay is not consumed but its moisture is expelled, its density and hardness are increased, and its plasticity destroyed. The changes which take place are partly chemical and partly physical.

Brick are first hardened by drying in the sun. The use of sun-dried brick dates back probably to 8000 B. C. Such brick are still used for building purposes in some arid or semi-arid regions. Burned brick were first used about 4500 B. C.

The process of burning consists of two periods, the water-smoking period and the burning period. The object of water-smoking is to evaporate the water in the clay, and for this purpose the temperature of the kiln is maintained at about 212° F. The production of too high a temperature may result in cracked brick from stresses set up by steam. The air which enters the bottom of the kiln soon becomes laden with moisture. Unless this moisture is removed, it may be condensed in some cooler portion of the kiln. The water thus formed upon the surface of the brick may soften them or produce kiln white. The moisture-laden air should be removed as rapidly as possible. At the beginning of the water-smoking period, a large amount of air should be allowed to enter the kiln, and be maintained until the ware is dry. As the temperature of the kiln increases, the amount of air may be gradually diminished. Wood is generally used for water-smoking, and it should be dry. The firing should be so conducted as to produce a slow fire and little flame. Hard wood and coke are said to give the best results.

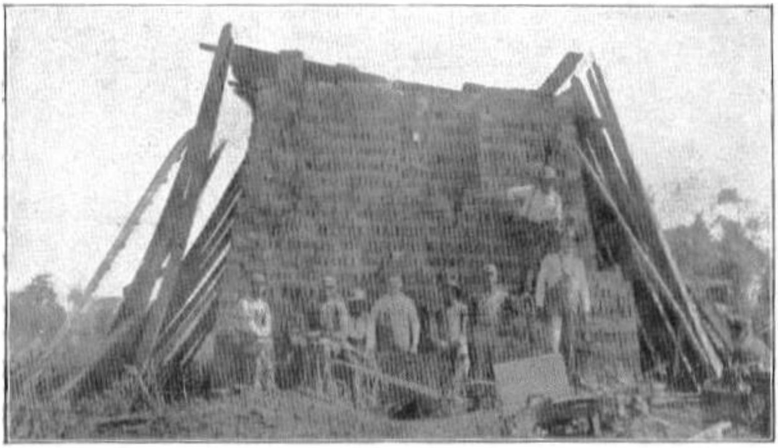
During the burning process, the temperature should be increased slowly until the temperature has reached 932° F. to 1,112° F., at which temperature the water of crystallization is driven off. After that, the temperature may be increased more rapidly until the point of incipient fusion is reached. The temperature may then be maintained until the heat has reached the center of the ware. Care must be exercised at this stage of the process, because in some clays the difference between incipient fusion and viscosity may not be very great.

In some parts of France, Belgium and England, brick are burned in the open by mixing the fuel and the raw brick. However, in most plants, the brick are burned in kilns.

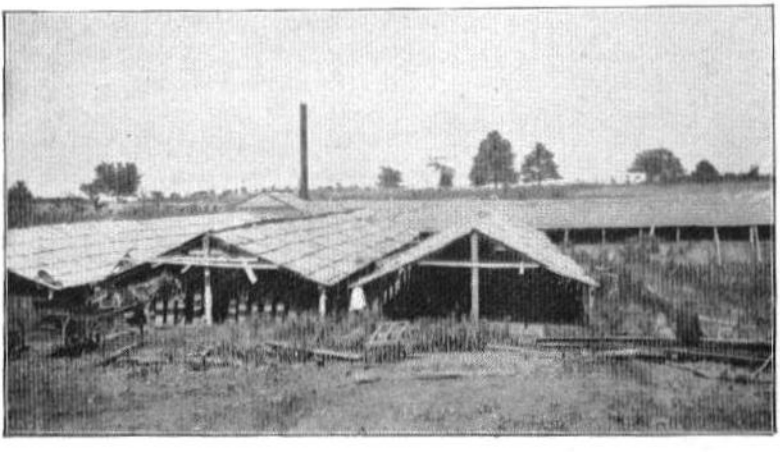
Types of Kilns.

Brick kilns may be classed according to the following outline:

Up-draft kilns.
    A. Scove kiln.
    B. Dutch or clamp kiln.
Down-draft kilns.
    A. Beehive kiln.
    B. Rectangular kiln.
    C. Continuous kiln.



A. SETTING BRICK IN A SCOVE KILN, STARKVILLE.



B. SHED DRYER, BRICK HACKED ON GROUND.

UP-DRAFT KILNS.

In the up-draft kilns, the heat passes through the brick in the kiln from the bottom toward the top. In the down-draft kilns, the heat is conducted through flues to the top of the kiln and from there it passes downward through the brick and is withdrawn through flues at the bottom of the kiln connected with stacks.

Scove kiln.—The scove kiln is the simplest type of kiln and because of its cheapness is much used in small plants. The brick are set in a rectangular mass and surrounded by a double wall of soft-burned brick. The outer surface of the wall is coated with mud in order to prevent loss of heat and the entrance of air. The fire boxes are made by setting the brick in the kiln in such a way as to form arches, which extend through the kiln from side to side. The fuel is placed in these arches from openings in the side walls. The top of the kiln is covered with a layer of brick laid flatwise and close together. The platting, as this layer is called, is sometimes partly or wholly covered with sand or clay, and the heat is directed by moving this loose material from point to point. The brick are protected from the weather during the setting and burning by a shed roof raised upon poles, which extend several feet above the top of the brick. The brick are laid in from 40 to 50 courses.

Scove kilns are employed mostly for burning common brick. Vitrified brick are not easily burned in them because of the difficulty of securing a high temperature. They are not suitable for some kinds of clay for a similar reason.

Dutch or clamp kilns.—The Dutch or clamp type of up-draft kiln is in more common use than the scove kiln. These kilns have permanent side walls of a thickness sufficient to retain more heat than the scove kiln. It is possible to secure a higher temperature in them. The brick are stacked within the walls of the kilns, arches being left and the top platted as in the case of the scove kiln.

In the up-draft kiln several courses of brick at the bottom are likely to be overburned, while the top courses are underburned. The brick in the arches are generally slaggy, brittle and discolored. The percentage of hard burned brick varies with the care exercised in burning. Rarely more than 70 per cent of the kiln may be classed as number 1 brick.

DOWN-DRAFT KILNS.

In down-draft kilns the fire boxes are outside the walls, and the heat is conducted to the top of the kiln, and after passing through the brick is drawn off by flues at the bottom through one or more stacks. Some of the advantages of this type of kiln are: (1) labor saved in platting; (2) heat more thoroughly and completely distributed; (3) no extreme heat in contact with brick; (4) small amount of waste due to misshapen brick, because the highest heat is at the top where there is the minimum weight. From a single burn in this type of kiln as much as 90 per cent of hard burned brick has been obtained.

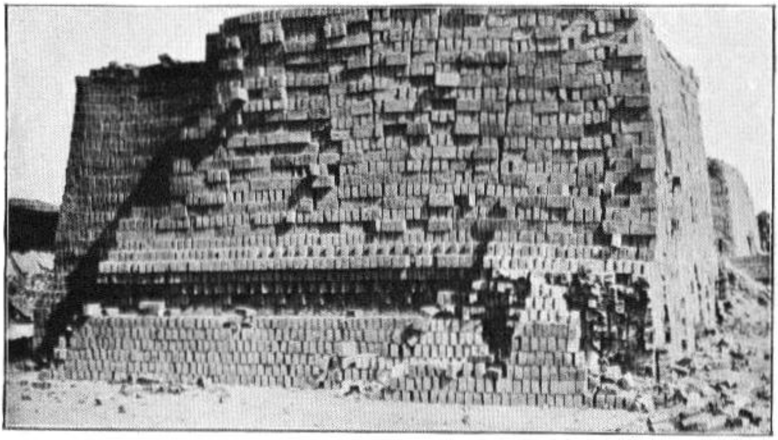
Beehive Kiln.—The beehive kiln is a circular down-draft kiln with an oval top. The kiln is supplied with one or more stacks. The gases are taken to these stacks from the bottom of the kiln by means of flues. It is essential that the kiln should have a uniform draft, and this is secured by construction of flues and arrangement of the wares within the kiln. The capacity of such kilns varies from 25,000 to 75,000.

Rectangular Kiln.—The down-draft rectangular kilns are of various types. They range in capacity from 150,000 to 300,000. They may be supplied with one large stack, into which more than one kiln may open. Each kiln may be supplied with two or more small stacks. The stacks are placed either at the side or end of the kilns.

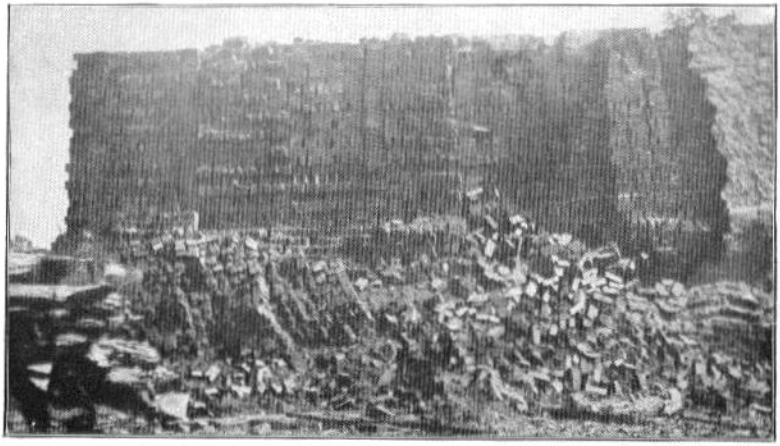
Continuous Kilns.—Continuous kilns are built with the object of using the waste heat from the cooling brick to water-smoke the unburned brick. In shape they may be circular, oval or rectangular.

The only one used in Mississippi is rectangular in form. It consists of 12 chambers arranged in two rows and separated by permanent walls. Each chamber has a capacity of 70,000 brick. Producer gas is used as fuel. The gas is conducted by conduits from the gas producer to the various chambers. The waste heat from the chamber in which the burning has just been completed is used to water-smoke the one which has just been filled. The transfer of waste heat may be made between any two of the twelve chambers. The gases and water from the chambers are taken through the flues to one large stack, located near the end of the kiln.

PLATE XXI.



A. BURNED BRICK IN A SCOVE KILN; GOOD BURN.



B. OVERBURN IN A SCOVE KILN; BOTTOM BRICK SLAGGY.

CHAPTER V.

FUEL.

Fuel may exist as a solid, a liquid or a gas. Among the various substances used for producing heat are included wood, sawdust, straw, bagasse, turf, peat, lignite, bituminous coal, cannel coal, anthracite, coke, charcoal, petroleum, furnace oil, shale oil, creosote, tar oils, natural gas, coal gas, water gas, gasoline gas, naphtha gas and producer gas.

The principle combustible elements contained in these fuels are carbon and hydrogen. In the process of combustion these elements are oxidized. The carbon (C) unites with oxygen (O) in the proportion of one part of carbon to two parts of oxygen, if enough of the latter is present, otherwise one part of each combines, forming in the first case carbon dioxide (CO_2), in the second case carbon monoxide (CO). The hydrogen unites with oxygen in the proportion of two parts of hydrogen to one part of oxygen, forming water (H_2O). Both of these chemical unions result in heat.

The number of heat units produced varies with different substances. The heat-producing power of a pound of various substances is given by Parsons in "Steam Boilers," as follows:

TABLE 19.

CALORIFIC VALUE OF DIFFERENT FUELS.

Hydrogen gas		62,032
Carbon to carbon dioxide		14,500
Carbon to carbon monoxide		4,400
Carbon monoxide to carbon dioxide		4,330
Olefiant gas		21,344
Liquid hydrocarbons (oils), varying with weight	19,000 to	22,600
Charcoal, from wood		13,500
Charcoal, from peat		11,600
Wood, dry	average	7,800
Wood, 20% moisture		6,500
Peat, dry	average	9,950
Peat, 20% moisture		7,000
Coal, anthracite, best quality	about	15,000
Coal, anthracite, ordinary		13,000
Coal, bituminous, dry		14,000
Coal, cannel		15,000
Coal, ordinary poor grades		10,000

CLASSES OF FUELS.

Wood.

Wood is composed of organic and inorganic matter and water. The first is combustible, the others are non-combustible. In the process of burning the water is vaporized. The organic matter is consumed, *i. e.*, it is transformed into invisible gases. The inorganic matter remains in the ashes. When wood has been dried at 300° F. it contains about 99 per cent of organic matter and 1 per cent of inorganic matter. The organic matter consists of carbon, 49 per cent; oxygen, 44 per cent, and hydrogen, 6 per cent.

When wood is heated above the temperature necessary to drive off its moisture, gases are generated which ignite, producing flame. The amount of heat produced depends upon the moisture condition of the wood. When thoroughly dry a given amount of pine will produce just as much heat as the same amount of hickory. Pine, however, produces more flame than oak or hickory, and not as good a bed of live coals. Under ordinary yard conditions the oak or hickory may be said to exceed the pine by 25 per cent in the production of heat.

Wood under ordinary conditions contains 25 pounds of water, 74 pounds of wood and 1 pound of ash for every 100 pounds. The wood portion consists of 37 pounds of carbon, 4.4 pounds of hydrogen and 32 pounds of oxygen. In the process of combustion 4 pounds of hydrogen unite with 32 pounds of oxygen, forming water. This leaves about half of the wood substance, 37 pounds of carbon and .4 pounds of hydrogen, as elements of combustion. One hundred pounds of green wood contains about 50 pounds of water. This wood is capable of producing 270,000 heat units. A heat unit is the amount of heat required to raise one pound of water one degree Fahrenheit. The same amount of wood containing 30 pounds of water will produce 410,000 heat units. Air-dried wood contains about 20 per cent of water, and 100 pounds of such wood is capable of producing 500,000 heat units. When the same amount of wood contains only 10 per cent of water it will produce 580,000 heat units. One hundred pounds of kiln-dried wood, containing 2 per cent of water, will produce 630,000 heat units (Bull. 10, U. S. Forestry Div., 1895).

These facts point clearly to the desirability of having on hand a good supply of wood, so that the use of green or even half-dried wood may be avoided. The wood should not be decayed nor should it be wet or green if the highest heating efficiency is to be obtained. The moisture in the wood must be converted into water vapor and a great deal of heat is consumed in this conversion.

Many of the brick plants of the State rely entirely upon wood for fuel. Nearly all use wood for water-smoking. Oak and yellow pine are the more common kinds used, but in some plants ash, gum, willow and other species are used. The price of wood generally varies with the abundance of accessible timber and the condition of the local labor market. The average price per cord paid for wood is two dollars. The maximum price paid is two dollars and eighty-five cents, and the minimum is one dollar and twenty-five cents.

Coal.

Varieties of Coal.—There are a number of varieties of coal, ranging from nearly pure vegetable fiber in peat to the highly carbonized and crystalline anthracite. The names applied to these varieties are peat, lignite, cannel coal, jet, bituminous coal, semi-anthracite and anthracite. These coals vary in the amount of carbon and hydrocarbons which they contain and in other constituents.

Peat.—Peat is an accumulation of vegetable matter which is thought to represent the first stage in the formation of coal. It is generally brownish-black in color and of light weight. It contains from 50 to 60 per cent of carbon, 5 or 6 per cent of hydrogen, and from 35 to 40 per cent of oxygen. Its fuel ratio is only .47 as compared with 28 in some anthracite coals. It is formed from the accumulation of vegetable matter in bogs and low marshy areas. A great deal of peat is being formed in glacial lakes and ponds by the growth of spagnum moss.

Lignite.—On account of its low stage in the period of coal development lignite is sometimes called "green" coal, but because of its color it is also called "brown" coal. It is usually brown or brownish black in color. Some varieties on fresh fracture present a shiny surface. It generally disintegrates rapidly when exposed to the air and breaks up into small cubes or laminae. It is supposed to represent a more advanced stage in the development of coal than peat. It contains less volatile matter than the latter and more fixed carbon. Its fuel ratio is about 1.50. It usually contains from 35 to 45 per cent of fixed carbon; from 5 to 20 per cent of ash, and from 25 to 30 per cent of hydrocarbons.

Bituminous Coal.—Bituminous coal is a soft coal more dense than lignite, and represents a more advanced stage in coal formation. It is of a deep black color and frequently has a rather distinct resinous luster. It burns with a smoky flame. When exposed to the air it does not disintegrate as readily as lignite and contains a higher percentage of fixed carbon. Its fuel ratio is more than double that of lignite. Bituminous coal contains from 65 to 85 per cent of carbon, about 5 per cent of hydrogen, and about 15 per cent of oxygen. Its specific gravity varies from 1.20 to 1.40. Bituminous coals may be divided into two varieties, coking and non-coking. Coking coals when ignited with air excluded may be changed to coke.

Anthracite.—Anthracite is the hardest form of stone coal. It has a sub-metallic luster and breaks with a conchoidal fracture. It is brittle and of a shining black color. It has a specific gravity of from 1.57 to 1.67. It has a low percentage of hydrocarbons and a high per centage of fixed carbon. For this reason it is difficult to ignite and burns without much flame. It has a high calorific value and when burned under the proper conditions produces an intense heat. Its fuel ratio may be as high as 28. It contains from 90 to 95 per cent of carbon. The per cent of hydrocarbons is from 3 to 5 per cent. Anthracite coal represents the last stage in coal metamorphism and has lost all traces of its vegetable origin.

Determination of the Calorific Value of Coals.—In the determination of coal constituents moisture, volatile and combustible matter, fixed carbon and ash are determined by weight; sulphur, iron and phosphorous by analysis. The value of any substance as a fuel is usually found by determining the power of a given quantity of the substance to evaporate water. The heat-producing power of a substance is termed its calorific value. The calorific value of a fuel may be obtained by determining the number of pounds of water which it will convert into steam at the boiling temperature of water under a pressure of one atmosphere by the consumption of one pound of fuel.

The calorific value of fuels may be determined by the calorimetric method, the computation method and the direct method.

In the calorimetric method a definite amount of fuel to be tested is burned in a chamber surrounded by a definite amount of water. The rise of temperature of the water is registered by a thermometer. The proportion of the fuel to the water used is one part of fuel to every 967 parts of water. This proportion is used because when water is converted into steam at 212° F., 967° F., or 537.22 gram degrees or calories of heat, disappear as latent heat. If the temperature of 967 parts of water be raised one degree, enough heat has been employed to convert one part of water into steam at 212° F. Thus the rise of temperature of the water as recorded by the thermometer will indicate the number of parts of water capable of being converted into steam by the heat produced by the fuel.

In testing coal by the calorimetric method it is reduced to a fine powder in order to secure perfect combustion. Since the fuel must be consumed in a closed vessel it is necessary, in order that its combustion may be complete, to add compounds which will supply oxygen. To furnish the oxygen supply the coal is mixed with potassium chlorate ($KCIO_3$) and potassium nitrate (KNO_3). The coal is consumed in a copper cartridge which fits into a cup-shaped receiver. A second copper cylinder with a valve tube at the upper end is placed over the first. A row of openings around the lower end of the second tube permits the escape of gases which are produced in the combustion. This apparatus is placed in a graduated glass cylinder which contains the water. The charge in the tube may be ignited by the use of a fuse of sufficient length to permit the apparatus to be placed in the vessel before the charge is ignited, and to cause ignition to take place by the time the apparatus reaches the bottom of the vessel. The charge may be ignited by means of an electric current.

The gases of combustion pass through the entire column of water and therefore their heat is lost to the water. The rate of combustion of the charge should be controlled so as to prevent too rapid evolution of gases, and at the same time the rate of burning should not be so slow as to cause loss of heat through radiation. The rate of combustion may be regulated by tamping the charge or by varying the amount of the oxygen-producing substances. As soon as the charge has been consumed the stopcock of the cartridge is opened so that the water may come in contact with all parts of the cartridge and extract its heat. To facilitate extraction the furnace may be moved up and down in the water. The temperature of the water should be taken before the charge is burned and at the close of the burning. The temperature of the water should always be lower than the temperature of the room.

Allowances must be made for heat absorbed by the gases of combustion, for heat produced by the decomposition of the oxygen compounds, for the loss of heat by radiation and conduction, and for heat absorbed by the apparatus. The total loss of heat from these sources is from 10 to 15 per cent.

By means of the chemical analysis of coals and the use of the following formula, the calorific value of a coal may be computed:

Total heat expressed in B. T. U. = $14{,}500\ C + 62{,}032\ (H - \frac{O}{8})$. The C is carbon, H is hydrogen and the O oxygen contained in the coal. They represent the amount by weight of each of these substances. The atomic weight of hydrogen is 1, the atomic weight of oxygen is 16. When they unite to form water they unite in the proportion of two H to one O or 2 to 16 (1 to 8). When present in the form of water they do not produce heat, hence $\frac{1}{8}$ of the oxygen is subtracted from the hydrogen. Another formula sometimes used is, total heat = $14{,}600\ C + 62{,}000\ (H - \frac{O}{8}) + 4{,}000\ S$, in which S represents the amount of sulphur present.

In the direct method of determining the calorific value, fuel is used to evaporate water under normal power plant conditions, and an accurate account of the number of pounds of coal used and the number of pounds of steam produced is kept for a definite period. In this way the evaporative power of different fuels may be determined and compared.

Since no coal is mined in Mississippi all our industrial plants are dependent upon other States for this class of fuel. Different parts of the State use coal derived from different sources. Some of the States from which our coal supply is drawn are Pennsylvania, Illinois, Indiana, Missouri, Arkansas, Tennessee, Kentucky and Alabama. We have very little information as to the calorific value of these different coals. The information given in the following table has been collected by Professor Albert Barnes, of the Mechanical Department of the Agricultural College of Mississippi. The tests were all made on Alabama coals:

TABLE 20.

CALORIFIC VALUES OF ALABAMA COALS.

Name of Coal.	*Kind of Coal.*	*Length of test in hours.*	*Weight of coal burned in pounds.*	*Weight of ash.*	*Weight of water evaporated.*	*Weight of water evaporated F. and A. 212° F.*	*Weight of water evaporated per unit of coal.*	*Cost of evaporating 100 pounds of water.*
Sterling L. Lanier, Agt	R. of M..	7	4,577	579	21,411	21,460	6.00	$0.02025
Gilnath Coal Co......	R. of M..	7	6,419	537	38,352	40,001	6.2	.0195
Corona Coal Co. (Annie Mae Mine)........	R. of M..	7	4,487	1,012	29,571	......	6.9	.0178
Carbon Hill coal (Kansas Mine).........	R. of M..	4	1,379	275	9,462	9,944	7.2	.0167
Hill Creek Coal Co. (Birmingham).....	R. of M..	8	5,603	311	34,250	......	6.417	.0195
Carbon Hill..........	R. of M..	12	6,236	.....	45,968	47,990	7.7	.0153
Tenn. Coal, Iron & R. R. Co..........	Lump...	10	5,642	486	47,514	49,604	8.7	.0150
Hill's Creek Coal Co..	R. of M..	18	13,386	11	99,730	......	7.73	.015925
Tupola Coal Co.......	R. of M..	4	2,833	....	17,600	20,768	7.33	.0187

R. of M.—Run of Mine.

Mississippi Lignites.

As stated in the foregoing pages no coal is mined in Mississippi, and, to the best of our present knowledge, we have no coal other than lignite. There are numerous beds of lignite occurring in the Wilcox strata of the Eocene and in some other horizons. Below is given the analysis and the calorific values of a number of these lignites. The samples were collected by Dr. Calvin S. Brown of the State Survey and the determinations were made under the direction of Dr. W. F. Hand, State Chemist.

TABLE 21.

COMPOSITION OF MISSISSIPPI LIGNITES.

Constituent	*No.* 10	*No.* 14	*No.* 15	*No.* 20	*No.* 43	*No.* 46
Moisture............	11.61	14.20	11.40	13.20	12.20	12.62
Volatile matter.....	34.61	35.24	32.61	40.16	46.27	40.85
Fixed carbon........	42.47	41.80	37.00	31.24	30.86	39.94
Ash.................	11.31	8.76	18.99	15.40	10.67	6.59
Total..........	100.00	100.00	100.00	100.00	100.00	100.00
Sulphur............	2.66	.63	1.50	1.20	.76	2.05

CALORIFIC VALUES.

Calories per gr......	5595	5255	5112	5050	5096	5392
B. T. U. per pound..	10071	9450	9201	9090	9173	9706

COMPOSITION OF THE ASH FROM LIGNITES.

Constituent	*No.* 14	*No.* 23	*No.* 25	*No.* 43	*No.* 46	*No.* 48
Silicon dioxide......	29.10	22.95	63.65	51.82	35.00	22.66
Aluminum oxide	13.45	12.37	13.25	26.98	17.00	14.88
Iron oxide..........	21.00	19.00	10.95	7.12	29.00	20.62
Calcium oxide.......	22.80	21.37	2.50	6.07	4.55	15.20
Magnesium oxide...	.19	.97	.90	.22	1.50	2.90
Sulphur trioxide....	8.53	14.70	4.46	5.45	6.34	19.89

Oil.

Mineral oils are now used for fuel in many industries. Petroleum is said to be used successfully in the burning of brick in some of the oil fields of the West. The oil is kept in tanks and fed into the fire box by means of an injector-nozzle. The blast from the nozzle produces a current of air which mingles with the oil and flame in the combustion chamber, thereby aiding combustion.

Petroleum, or crude oil, is a liquid of complex composition. It is composed largely of a mixture of hydrocarbons. There are two general classes of petroleum, viz.: those having a paraffin base and those having an asphaltum base. Chemically petroleum is composed of carbon, hydrogen and oxygen. The percentage of carbon varies from 82 to 87 per cent; hydrogen from 12 to 14.8 per cent, and oxygen from 1 to 6 per cent. The specific gravity ranges from .80 to .983. A gallon of petroleum weighs from 6.5 to 7.8 pounds. A pound of oil will produce from 19,000 to 22,000 heat units and will evaporate from 19.6 to 22.7 pounds of water.

The results obtained from the use of petroleum for boiler fuel at the World's Fair at Chicago in 1893 were as follows:

TABLE 22.

AMOUNT AND COST OF PETROLEUM FOR BOILER FUEL.

Consumption of oil per hour..................................	22,792 pounds
Water evaporated from 212° F. into steam at 125 pounds, per pound of oil..	14.25
Equivalent evaporation from and at 212° F....................	14.88
Cost of oil per hour..	$56.20
Cost of oil per boiler horse-power per hour......................	.0057
Cost of labor per boiler horse-power per hour....................	.0006
Cost of boiler horse-power per hour............................	.0063

Repeated experiments seem to have demonstrated that in evaporative power one pound of oil is equivalent to two pounds of coal. The causes of the superiority of oil are summed up by Parsons in *Steam Boilers* as follows:

"1. The combustion of the liquid fuel is complete, whereas that of coal is not, consequently in the former case there is no lost heat in smoke or soot.

"2. There are no ashes or clinkers, and consequently no fires to clean with the accompanying loss of heat and drop in the steam-pressure.

"3. The boiler-tubes are always free from soot and clean, and therefore always in the best condition for transmitting the heat from the gases passing through them to the water of the boiler.

"4. The temperature of the escaping gases may be considerably lower than is required to create the draft necessary for coal-firing.

"5. The admission of air being under complete control, and the fuel being burned in fine particles in close contact with oxygen of the air, only a small excess of air above that actually necessary for the combustion of the fuel is required. With coal, in order to insure as complete combustion as possible, a very much larger excess of air is required."

Gas.

Natural gas has not been discovered in appreciable quantities in Mississippi or in the territory immediately adjacent. For this reason this form of fuel is not used in any of our industrial plants. Artificial gas, called producer gas, is used in one of the clay plants of the State for burning its ware. The gas is manufactured by injecting steam upon a bed of burning soft coal. The gas is used in a chambered continuous kiln. By the use of this form of fuel there is said to be a large saving in labor and fuel. Twenty-six hundred feet of natural gas is equivalent, in heating power, to a good average ton of coal. It would, however, require 100,000 feet of some of the poorer artificial gases to be of equal value.

The composition of natural gas and some of the artificial gases is given in the following table from Kent's Mechanical Engineer's Pocket-book:

TABLE 23.

COMPOSITION OF FUEL GASES.

	Natural	*Coal*	*Water*	*Producer-gas*	
Constituent	*gas*	*gas*	*gas*	*Anthracite*	*Bituminous*
CO	0.50	6.0	45.0	27.0	27.0
H	2.18	46.0	45.0	12.0	12.0
CH_4	92.60	40.0	2.0	1.2	2.5
C_2H_4	.31	4.0	....	....	.4
CO_2	.26	.5	4.0	2.5	2.5
N	3.61	1.5	2.0	57.0	56.2
O	.34	.5	.5	.3	.3
Vapor	....	1.5	1.5	....	....
Weight in pounds of 1,000 cubic feet	45.60	32.0	45.6	65.6	65.6
Heat units in 1,000 cubic feet	1,100,000	735,000	322,000	137,455	156,917

The same author gives the following fuel values for the different kinds of gaseous fuels:

TABLE 24.

FUEL VALUE OF GASES.

Kind of gas	*No. of heat units in* 1,000 *cubic feet used*	*No. of heat units in furnaces after deducting* 25% *loss*	*Average cost per cubic foot*	*Cost of* 1,000,000 *heat units obtained in furnaces*
Natural gas	1,000,000	750,000	....	....
Coal-gas, 20 candle power	675,000	506,250	$1.25	$2.46
Carburetted water-gas	646,000	484,500	1.00	2.06
Gasoline-gas, 20 candle power	690,000	517,500	.90	1.73
Water-gas from coke	313,000	234,750	.40	1.70
Water-gas from bituminous coal	377,000	282,750	.45	1.59
Water-gas and producer-gas mixed	185,000	138,750	.20	1.44
Producer-gas	150,000	112,500	.15	1.33
Naphtha-gas, fuel 2½ gallons, per 1,000 feet	306,365	229,774	.15	.65
Coal, $4.00 per ton, per 1,000,000 heat units utilized	....	....	....	.73
Crude petroleum, 3 cents per gallon, per 1,000,000 heat units	....	....	....	.73

CHAPTER VI.

PROPERTIES OF BRICK.

EARLY HISTORY OF BRICK.

According to present historical knowledge clay was first employed for structural purposes in Babylonia.* This country is partly an alluvial plain bordering on the Persian Gulf. The plain is drained by the Tigris and the Euphrates rivers and is probably very similar in origin to the Yazoo basin of the Mississippi. This plain, like others of its kind, is devoid of ledges of hard rock which can be used for structural purposes. So the early inhabitant, not finding the rock with which to construct his house, was compelled to employ a substitute. Hence brick—another proof that necessity is the mother of invention. Down beneath the drifting sands of the plain the early inhabitant of Babylonia found a plastic clay which he could mold and fashion into brick. Thus brick and other clay wares were manufactured, probably 8,000 years before the beginning of the Christian Era.

The first brick were irregular rectangular masses of clay dried in the sun. Brick were not burned until about 4500 B. C. The first burned brick were small, flat upon one side and rounded upon the other, or plano-convex brick with rounded corners. These brick were set upon edge in the wall, the spaces being filled in with mud or bitumen. Forty-five varieties of these early brick have been discovered in excavations recently made in Bismya.

BRICK TESTS.

In order to determine the wearing qualities of brick a series of tests is employed. These tests determine the amount of load required to break the brick crosswise, transverse strength; the amount of load required to crush the brick, crushing strength; the number of pounds of pull the brick will stand, tensile strength; the

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*Banks, Clay Products of Early Babylonia, Clay Worker for January, 1907.

amount of water the brick will absorb, absorption test; the amount of knocking about required to destroy the brick, impact test; and the amount of freezing the brick will stand without deterioration. These tests are not so essential in small buildings, but in large structures, and especially in paving work, they are very essential. However, only four are considered of leading importance, viz.: transverse strength, crushing strength, impact strength, absorption.

Crushing Strength.

The crushing strength of a brick is expressed in the number of pounds of pressure per square inch of surface that a brick will stand. The object of the test is to determine how much load the brick are capable of supporting when placed in a wall. The crushing strength of brick varies from 500 pounds to 15,000 pounds per square inch.

The weight of an ordinary brick is about 5 pounds. When laid flatwise a standard brick has an exposed top area of 32 square inches. Each brick laid upon this surface exerts a pressure of about $\frac{1}{6}$ of a pound per square inch. Every six bricks then exert a pressure of 1 pound per square inch. Therefore, in a wall 100 feet high the pressure exerted upon the bottom layer of brick, if the weight of the brick only is considered, is only 100 pounds per square inch. From these facts it will readily be seen that the crushing strength of brick is not likely to be overtaxed in construction work. The crushing strength of brick is tested in machines specially constructed for the test. In soft-burned brick the crushing strength may be as low as 40 pounds per square inch.

In making the test, parallel edges of the half of a brick are ground smooth and the brick is then placed between the bearing plates of the machine. The load is increased gradually until the strength of the brick is reached when it falls into pieces with a loud report.

Absorption.

Brick are porous. That is, they contain spaces not occupied by clay particles. The degree of porosity is determined by the amount of water that the brick will absorb. The porosity of a brick may depend upon a number of factors. It may depend upon the character of the clay used. A coarse, sandy clay will produce a more porous brick than a more aluminous clay. It may depend upon the degree of burning, as a soft-burned brick will absorb more than a hard-burned brick. It may also depend upon the process of molding. Soft-mud brick, as a rule, are more porous than stiff-mud brick.

The percentage of absorption in Iowa common brick ranges from 9.5 per cent to 22.7 per cent. One paving brick tested absorbed 4.7 per cent.*

New Jersey soft-mud brick range from 5.36 per cent to 18.64 per cent, while stiff-mud brick range from 1.34 per cent to 14.29 per cent.†

The following tests were made upon some bricks from this State. The samples tested, after being carefully dried, were weighed and then immersed in water for 48 hours. Upon being taken from the water, the moisture adhering to their surfaces was removed and they were reweighed. The difference between the weight of the dry brick and the wet brick gave the amount of water absorbed. By dividing this difference by the weight of the dry brick the percentage of absorption was determined.

TABLE 25.

ABSORPTION TESTS OF MISSISSIPPI BRICKS.

Locality	*Color*	*Make of brick*	*Per cent of absorption*
Stonington	Red	Pressed	10.52
Yazoo City	"	"	15.00
" "	"	"	15.00
" "	"	"	15.00
Oxford	"	"	14.09
"	"	"	12.50
"	"	"	12.76
"	"	"	13.04
"	White	"	15.00
Starkville	Red	Stiff mud (repressed)	22.22
"	"	" "	10.52
"	Chocolate	" "	5.00
"	Iron color	" "	5.26
"	"	Stiff mud	8.10
"	Red	"	5.26
Columbus	Chocolate	"	21.21
"	Red	"	15.74
Amory	Chocolate	"	15.00
"	Red	"	9.75
Maben	Chocolate	"	8.80
"	Red	"	16.86
"	White	"	26.86

It is thus seen that the percentage of absorption in dry-pressed brick ranges from 10.52 to 15 per cent. The percentage of absorption

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*See Vol. XIV, Iowa Geol. Sur., p. 595.

†See Vol. VI, N. J. Geol. Sur., pp. 254–5.

in repressed brick ranges from 5 to 22.22 per cent. The percentage of absorption in stiff-mud brick ranges from 5.26 to 26.82 per cent. In the manufacture of these brick different kinds of clay were used and the degree of burning varied. All of those exhibiting a high percentage of absorption were soft-burned.

Impact Strength

Rattler Test.—Brick for the rattler impact test are placed in a polygonal cast-iron barrel which is made to revolve on trunnions. The length of the barrel is 20 inches and its diameter is 28 inches. It is a regular polygon of 14 sides. The brick are placed in the barrel together with a charge of cast-iron blocks. The barrel is then moved at a certain speed for a definite number of hours. The strength of the brick is then estimated by the amount of loss it has sustained due to abrasion. The charge consists of 12 brick and 300 pounds of iron blocks of two sizes. First, cubes of 1½ inches in diameter having a collective weight of 225 pounds; second, blocks 2½ inches square and 4½ inches long with rounded edges and a collective weight of 75 pounds. The number of revolutions required for the test is 1,800 at the rate of 80 per minute. The brick must be perfectly dry. The loss is computed as per cent of the dry brick and the average of two tests taken

The rules for this test, adopted by the National Brick Manufacturers' Association, are as follows:

"The standard rattler shall be 28 inches in diameter and 20 inches in length, inside measurements. Other dimensions may be employed between 26 and 30 inches diameter and 18 to 24 inches length, in which case the dimensions should be stated in reporting the test. Longer rattlers may be employed by the insertion of a diaphragm.

"The barrel should be supported on trunnions at the ends with no shaft running through the rattling-chamber. The cross section should be a regular polgyon of 14 sides. The heads shall be of gray cast iron, not chilled or case-hardened. The staves shall preferably be composed of steel plates, as cast iron peens and ultimately breaks from the wearing action on the inner side. There shall be a space of one-fourth an inch between the staves for the escape of dust and small pieces. Machines having from 12 to 16 staves may be employed, with openings from ⅛ to ⅜ inch, but these variations from the standard should be mentioned in an official report.

"The charge shall consist of but one kind of brick at a time, nine paving blocks or twelve bricks being inserted, together with 300 pounds of cast-iron blocks. These shall be of two sizes, 75 pounds being of the larger and 225 pounds of the smaller size. The larger size shall be about 2½ inches square and 4½ inches long, with slightly rounded edges. All blocks shall be replaced by new ones when they have lost 10 per cent of their original weight.

"The number of revolutions shall be 1,800 for a standard test at a speed between 28 and 30 per minute.

"The bricks shall be thoroughly dried before testing. The loss shall be calculated as per cent of the weight of the dry bricks composing the charge, and no result shall be considered as official unless it is the average of two distinct and complete tests made on separate charges of brick." (Materials of Construction, Johnson, p. 461a.)

Tensile Strength.

The tensile strength of ordinary brick varies from 40 to 400 pounds per square inch. The test is made by placing the specimen in the jaws of a machine and measuring the amount of pull necessary to break the section. The tensile strength of a large number of Mississippi brick clays was tested in both the raw and the burned state. These results are recorded under the discussion of the individual clays. No tests have been made upon the manufactured product of the various plants. The tensile strength of some of the burned clays ranges as high as 800 pounds per square inch.

Transverse Strength.

The transverse strength of a brick is measured by the load it will sustain when unequally supported. For example, suppose a brick to be supported at each end and a load applied to a point midway between the supports. When the load added reaches the transverse strength of the brick the brick will be broken crosswise. The modulus of rupture is calculated by the use of a formula in which

R = Modulus of rupture.
W = Pressure of load.
l = Distance between supports.
b = Breadth of brick.
h = Thickness of brick.
and $R = \frac{3Wl}{2bh^2}$

Now, if a weight of 3,000 pounds be applied to a brick 4 inches wide and 2 inches thick, where the distance between the supports is 4 inches, its transverse strength will be as follows:

$$\frac{3\times 3000\times 4}{2\times 4\times 2}=1,125 \text{ pounds.}$$

Weight of Brick.

Common brick, having a size of 8¼ x 4 x 2 inches, have an average weight of 4½ pounds. One thousand of such brick have a weight of 4,500 pounds or 2.01 long tons. Pressed brick of standard size have an average weight of 5 pounds and weigh 2.23 tons per 1,000.

The average weight of 10 Mississippi pressed brick is 5.6 pounds. The average weight of 10 repressed brick of stiff-mud make is 4.7 pounds. The average weight of 10 stiff-mud brick is 4.6 pounds. These brick represent different kinds of clays and different sizes of molds.

Size of Brick.

The size of a standard brick is 8¼ inches long by 4 inches wide by 2 inches thick. A brick of this size contains 66 cubic inches. It requires 26.2 bricks of standard size to make 1 cubic foot and 707 standard brick to make 1 cubic yard.

The following table exhibits the sizes of some Mississippi brick. These brick vary in volume from 64 cubic inches to 95 cubic inches. One, alone, falls below the volume of a standard brick, and that one by 2 cubic inches only.

TABLE 26.

SIZE OF SOME MISSISSIPPI BRICK.

Number of Sample	*Color*	*Hardness*	*Size—Inches*	*Make*	*Formation*	*Volume*
Number 1	Red	Medium	8½ x 4 x 2½	Pressed	Residual loess (B. loam)	85 cubic inches
" 2	Red	Hard	7⅞ x 3 11/12 x 2 5/12	"	" " "	74 "
" 3	Red	Medium	8½ x 4⅛ x 2 11/16	"	" " "	95 "
" 4	White	Medium	8¼ x 4 1/12 x 2½	"	Wilcox	84 "
" 5	Iron black	Hard	7 11/12 x 3¾ x 2⅛	Repressed	Selma residual	64 "
" 6	Chocolate	Hard	7 11/12 x 3⅝ x 2¼	"	" "	68 "
" 7	Red	Medium	8 x 4 x 2⅛	"	" "	69 "
" 8	Chocolate	Medium	8⅛ x 4 x 2⅓	Stiff mud	Y. loam (2d bottom)	76 "
" 9	Bright red	Soft	7 11/12 x 3 11/12 x 2 5/12	"	" "	74 "
" 10	White	Soft	8 x 3¾ x 2⅓	"	" "	70 "
" 11	Dark red	Medium	7⅝ x 4 x 2 5/12	"	" "	75 "
" 12	Iron black	Hard	8 1/12 x 3⅝ x 2⅛	"	Selma residual	67 "
" 13	Red	Medium	7 11/12 x 3¾ x 2¼	"	" "	66 "
" 14	Chocolate	Hard	8¾ x 4 1/12 x 2 5/12	"	Y. loam (2d bottom)	83 "
" 15	Red	Medium	8⅞ x 4½ x 2⅓	"	" "	81 "
" 16	Chocolate	Hard	8¼ x 3 11/12 x 2¼	"	" "	72 "
" 17	Red	Medium	8⅛ x 4 x 2¼	"	" "	73 "
" 18	White	Soft	8⅛ x 4⅛ x 2 7/12	"	Wilcox	87 "

Variation in the size of brick may be due to a number of factors, viz.: (*a*) size of the die, (*b*) wearing of the die, (*c*) shrinkage of the clay, (*d*) degree of burning, (*e*) load in kiln, (*f*) method of molding.

The dies used by different manufacturers are not of uniform size. Even in the same machine the dies may vary in size, depending usually upon the desire of the manufacturer for a larger or smaller brick. The wearing of the die will incerease the size of the brick. Some manufacturers put in a new die at the beginning of each new kiln. The last brick made by an old die are sometimes as much as ⅛ of an inch wider and thicker than the first ones molded.

Variability is produced by a difference in the amount of shrinkage in clays. Even in clays from the same pit there may be a marked difference in the shrinkage. In surface deposits the top clays shrink less than the bottom clays. Numbers 3 and 4 of the table given above were molded by the same machine and burned to the same degree. The variation in volume (11 cubic inches) is due entirely to the difference in the shrinkage of the clays. No. 3 was made from the brown loam and No. 4 from the Wilcox. Nos. 14 and 15, made by the same machine under uniform conditions, represent the variability produced by different degrees of burning.

Three sizes of brick may be produced in the same kiln. In an up-draft kiln the top brick are larger than the middle brick, and the latter larger than the lower brick. Exceptions may be produced in some kilns by the expansion of certain kinds of clay at the point of viscosity.

The size of a brick will also depend upon the amount of load it sustains in the kiln. The weight of superincumbent brick may compress the lower brick, when near the point of viscosity, causing a loss of width which may be partly compensated by a gain in length, but resulting on the whole in a loss of volume. Another cause for variation in size of brick will be found in the different methods of molding employed, viz.: whether soft-mud, stiff-mud or dry-press.

The importance of the size of brick to the consumer is readily demonstrated. For instance, it requires 26.2 bricks of the standard size to make 1 cubic foot and 707 bricks for 1 cubic yard. Now, if the brick are smaller by one-fourth inch in each dimension there will be a decrease of 13.5 cubic inches in volume per brick, and it will require 25 per cent more brick for each cubic foot. The cost of building will thus be increased about 25 per cent.

As will be seen from the table, only one of the Mississippi brick falls below the standard size. This one represents the minimum size of that manufacturer, and the small size is due to excessive shrinkage in the clay, not enough non-plastic material being used in that run.

Number of Brick in Construction Work.

The number of brick of standard size (8¼ x 4 x 2 inches) required in walls, allowance being made for waste:

1 square foot of a wall 1 brick thick will require 14 brick.
1 " " " " 1½ " " " " 21 "
1 " " " " 2 " " " " 28 "
1 " " " " 2½ " " " " 35 "
1 " " " " 3 " " " " 42 "

An English rod of brick contains 306 cubic feet and requires 4,500 brick.

One bricklayer with a helper will lay 1,500 brick in a day of ten hours when working on an ordinary wall. In face or front work, he will lay from 1,000 to 1,200.

The number of brick of standard size required per square yard in sidewalk work is 38 brick, providing they are placed flatwise. If placed edgewise the number required is 73, and when placed endwise 149 are required. One man with a helper will place 2,000 brick in a day of ten hours.

Varieties of Brick in a Kiln.

In the down-draft kiln the top course is generally discolored with soot and ashes. The first two or three courses are sometimes brittle. As a usual thing these courses contain very hard brick, because they are subjected to the highest heat of the kiln. They may, however, because of rapid cooling, be deficient in toughness.

The shape of the brick of the top courses in a down-draft kiln is generally excellent, for the reason that there is no weight resting upon them to cause distortion. The conditions of burning make them very desirable for sewers and foundations.

The lower courses in down-draft kilns are liable to be under-burned or soft brick. The number of courses of soft brick, varying with the conditions of the burning, may be from two to ten courses. They are generally classified as No. 2 building brick and are used for backing.

The courses between the brittle top courses and the soft lower courses are classed as hard-burned brick. They are characterized by a tough, homogenous, hard body and a fairly uniform color.

The degree of vitrification is determined by the depth of the kiln marks, the limits for hard brick being placed at $\frac{1}{8}$ and $\frac{3}{8}$ inch.

CHAPTER VII.

IMPERFECTIONS OF BRICK.

Imperfections of brick arise from a number of causes. The character and causes of some of the more common imperfections in brick are discussed in the following pages.

DEFECTS OF FORM.

SWOLLEN BRICK.

If the temperature of a brick is raised rapidly so that the outside becomes vitrified before the gases have been expelled, swollen brick will result. For example, suppose a brick contains a high per cent of calcium carbonate ($CaCO_3$). By the action of heat the $CaCO_3$ is converted into CaO (lime), and CO_2 (carbon dioxide), a gas. Now, if the outside of the brick reaches the density and viscosity of vitrification before the gas has all been expelled, the gas will be temporarily confined, and the expansion due to the confined gas will cause a swelling of the brick. This is especially likely to occur in the case of the occurrence of nodules of calcium carbonate or pyrite in the clay.

Clay also contains gypsum, calcium sulphate, which when heated evolves a gas. The chemical symbol for gypsum is $CaSO_4$, $2H_2O$. At a temperature varying from 212° F. to 932° F. the water (H_2O) is drawn off. At a still higher temperature the SO_3 (a gas) is separated, leaving CaO. If the outsides of the brick have reached the stage of viscosity at the time of the evolution of the gas swollen brick will result.

Some clays which are used in the manufacture of brick contain very appreciable quantities of organic matter. In the combustion of this organic matter gaseous products (hydrocarbons) are formed. If the outer surface of the brick should become viscous before the hydrocarbons are all expelled, the expansive force of these gases may result in swollen ware. (A pound of carbon requires $2\frac{2}{3}$ pounds of oxygen for combustion and produces $3\frac{2}{3}$ pounds of CO_2.)

WARPED BRICK.

Warping of brick may be caused either in drying or in burning. Brick so placed in the dryer that they will dry faster upon one side than the other may warp. This is a common result when soft-mud brick are left too long upon the flat side in the open yard. Less often they warp when placed upon pallets in racks. Strong currents of air may produce such results even in the racks.

Warping may result in the kilns when one side of a brick reaches the point of viscosity while the other side is still solid. Warping of brick in a kiln is commonly produced by careening, that is, is a differential settling of the brick in the kiln. The brick in this section of the kiln soften, shrink and settle. Since the brick in the kiln are all bound together in setting, the unequal settling will cause some of them to be stressed. If they are soft enough to yield to the strain they will be warped, otherwise they will be broken. Careening is caused by faulty methods of firing. Too rapid firing in some parts of the kiln causes the heat to be drawn to one place, and chokes up parts of the kiln with smoke or soot.

CRACKED BRICK.

Too rapid drying results in differential shrinkage which produces cracks. When moisture is removed from the brick too rapidly it causes the outside to shrink more rapidly than the interior, thus subjecting the exterior to stretching, which results in breaking. Extremely sandy and extremely plastic clays are, as a rule, tender and require careful handling in the first extraction of moisture. Exposure to full and free circulation of the air is generally fatal to such clays. They should be protected from drafts for from six to twelve hours when first placed to dry. If a steam dryer is used, they should first be put into a tempering chamber and thoroughly heated before being placed in the dryer where the circulation might otherwise remove the moisture too rapidly.

Differential shrinkage, caused by too rapid loss of moisture along laminations, is another cause of cracks in brick. This is a common defect in certain clays used for the manufacture of brick by the stiff-mud auger-type machine. Frequently the laminations which remain almost invisible in the air-dried brick will be greatly developed in burning, due to the accumulation of gases along the laminæ. They are generally more harmful in side-cut brick than in end-cut. The clay is generally too plastic and should be tempered by the addition of non-plastic material. In surface deposits the bottom clays are likely to produce laminæ, and more of the top clay should be added. Laminations may be at least partly obliterated by repressing.

The presence of lime nodules which are calcined in burning frequently cause cracking and bursting of the brick. The heat and stresses set up by the hydration of the lime after the brick leave the kiln are the immediate causes. Brick containing these blebs of quick lime may be taken from the kiln in perfect condition, but after being exposed to a moist atmosphere the slaking of the lime will cause the brick to pop open. The product of an entire kiln may thus be lost. The amount of lime may not be excessive if it is ground fine and thoroughly mixed in the clay. The clay, however, could not be burned at a high temperature because of the fluxing action of the lime. According to Reis, calcareous clays containing as high as 20 per cent of calcium carbonate have been successfully used in the manufacture of clay wares.

DEFECTS OF COLOR.

LIGHT COLOR IN RED-BURNING BRICK.

Light color in red-burning brick may be the result of a number of conditions. The red color of burned clay is due to the oxidation of the iron compounds in the clay. The iron may be changed to ferrous oxide (FeO) or to ferric oxide (Fe_2O_3). Once changed to the oxide condition it will so remain until the point of vitrification is reached, when the iron may unite with silica and form silicates of iron. Light-colored brick may result if the total amount of iron in the clay is small. The amount of iron in clays ranges from less than 1 per cent in white-burning clays to 5 per cent or more in red-burning clays. The clay may contain the amount of iron requisite for a red-colored product and yet the ware be light in color because it has been burned at a low temperature.

The presence of lime in a clay may cause a light-colored product, notwithstanding the fact that a larger amount of iron is present than would produce a red-colored ware under normal conditions. Clay No. 32 from West Point contains 8.75 per cent of iron—double the amount necessary, under normal conditions, to produce red brick. The analysis of the clay shows the presence of 3.75 per cent of calcium oxide. This amount is abundantly sufficient in this instance to destroy the effect of the iron oxide and produce a pale yellow brick.

Deficiency in the amount of oxygen during the burning may be the cause of light colors in burned clay wares. If iron is oxidized in an atmosphere deficient in oxygen the ferrous compound (FeO) will be formed. Ferrous oxide produces a green color. Ferric oxide is red or purple. Oxygen deficiency may arise from insufficient draft in the kiln. Not enough oxygen is supplied to form the ferric compound. The conditions may be aggravated by the presence of carbonaceous matter in the clay. The carbon in the process of oxidation would rob the iron of oxygen and reduce it to the ferrous state.

EFFLORESCENCE.

Brick sometimes have their surfaces discolored by a white or yellowish substance called whitewash or efflorescence. This whitewash may appear on the brick during the process of drying. The water which comes from the interior of the brick by capillary attraction is evaporated at the surface and leaves behind its soluble salts which form the efflorescence.

Kiln White.—Brick which do not develop any efflorescence during the process of drying may do so during the burning period. The form of whitewash, called kiln-white, is composed of sulphates of calcium, magnesium, potassium, sodium and aluminium. All except the first named occur in very small quantities. These soluble salts may be present in the clay, they may be in the water used for tempering and they may be developed by reactions between kiln gases and constituents of the clay.

The calcium sulphate in clays is often developed by the oxidation of iron pyrites which produces sulphuric acid, which in turn attacks the calcium carbonate of the clay forming calcium sulphate. For the chemical reaction which takes place see page 55, under Gypsum. This salt is then deposited on the surface during the drying process. These salts are not liable to occur in the upper part of surface clay deposits but they are sometimes abundant in residual clays formed from limestone, especially along the line of contact.

Kiln-white is also produced by the union of sulphur dioxide from the fuel gases with calcium or magnesium in the clay products. Frequently the water used in tempering clay is taken from ponds which are made on or near limestone and clay contact. Such water is generally the source of efflorescence.

Wall-White.—Efflorescence which appears upon the brick after they are placed in the wall is termed wall-white. Wall-white is produced by the deposition of soluble salts on the surface of the brick through the evaporation of absorbed water from the interior of the brick. These salts are formed by chemical reactions taking place during the process of burning. The chemical reactions are usually between sulphuric acid derived from fuel gases and calcium or magnesium in the clay. After the brick are placed in the wall they may absorb water, which will take these salts into solution. The salts are then drawn to the surface of the brick by capillarity and, when the water is evaporated, they are left as a white, powdery coating on the surface of the brick.

The following means of prevention of kiln-white have been suggested:*

"1. Use the clay before the soluble salts form, *i. e.*, unweathered. Since the sulphates in the clay nearly always result from the weathering of its pyrite, it is often possible to avoid the whitewash simply by using the clay fresh from the bank, rejecting that which has been exposed to the weather any length of time. This is only possible with clays that lie below the permanent water level. This use of the clay, however, leaves the pyrite in the clay, and as has been shown, it will sooner or later come out as efflorescence on the walls. While the manufacturer is thus enabled to produce a clean brick, he is simply passing the trouble on to the user of his wares.

"2. Remove the soluble salts entirely from the clay, *i. e.*, weather it thoroughly, thus causing the washing out of the salt. Since the whitewashing salts are all soluble, or can be rendered so by weathering, it is possible to remove them entirely by exposing the clay to the action of the air, rain and frost as long as is necessary. As the action is slow and will not penetrate the clay unaided, the clay should be spread in thin layers and worked over occasionally. As the object is to remove

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*Jones in Brick, Vol. XXVI, p. 89.

the salts entirely, the ground upon which the clay is spread should slope enough to thoroughly drain the water away from the clay after it has done its work. This process not only removes the whitewashing salts but also increases the plasticity of the clay. The process takes several months and is too expensive on that account for most brick plants.

"It is possible to remove those soluble salts already formed in the clay by washing it. In using this process it must be borne in mind that the object is to remove the impurities and soluble salts and consequently a good supply of water must be at hand. In one case, at least, the water was being used over and over again until gypsum crystals of good size could be found quite plentifully in the storage tank of the washer. As in the process of weathering, the washing not only removes the salts but gives a more homogenous and better product. Its only disadvantage is the increased cost, which need not be large if a good supply of water is to be had.

"3. Transform the soluble salts to a harmless form by precipitation. The method in most common use to transform the soluble into insoluble sulphates is to mix amounts of barium carbonate or chloride with the clay. When either of these salts is introduced into a clay containing soluble sulphates, the barium combines with the sulphur and forms barium sulphate, one of the most insoluble compounds known.

$$BaCO_3 + CaSO_4 = BaSO_4 + CaCO_3$$
$$BaCl_2 + CaSO_4 = BaSO_4 + CaCl_2$$

"As the barium sulphate is very insoluble and is not decomposed during the burning the sulphur is firmly locked in the interior of the brick as long as the brick endures.

"Barium carbonate is also a very insoluble compound and must be ground finely and very thoroughly mixed with the clay to accomplish the end that is sought. A German writer recommends that it be ground in a tube mill together with fine sand, which has the effect of soon reducing it to the very fine powder that is wanted. The correct amount, which necessitates a chemical analysis for its determination, is then added to the clay as it enters the pug mill. The carbonate is perfectly safe to use, as neither an excess of the barium nor the calcium carbonate formed will cause efflorescence. Its success depends upon the thoroughness with which it is ground and mixed with the clay.

"The chloride, on the other hand, is soluble and consequently does not need much care in grinding and mixing. As it is soluble, it is rather dangerous to use, for any excess is carried to the surface of the brick and forms there a whitewash with the sulphur in the kiln gases. Its by-product, calcium chloride, is also soluble and is liable to form whitewash in the same way. The Germans frequently use both the carbonate and the chloride, adding enough of the chloride to overcome most of the whitewash, and depending upon the carbonate to take care of whatever whitewashing salts remain.

"4. Prevent the concentration of the salts on the surface of the brick by rapid firing. It is often possible when clay shows a tendency to whitewash, to hold the whitewash inside the brick by drying as quickly as possible. The mechanics of this is simple, and depends on the property of capillary tubes. When the brick is dried quickly the water is evaporated before the salt reaches the surface in sufficient quantities to cause trouble. When the clay will not permit of rapid drying the method cannot be used.

"5. Remove the whitewash in the kiln by the use of a reducing flame. The sulphates once formed cannot be decomposed or removed in an oxidizing flame at any temperature ordinarily reached in the kiln. In a reducing flame the sulphates are reduced at temperatures of 1,832° F. to sulphides. The bases enter into combination with the silicates of the brick, while the sulphur is driven off with the gases. By the use of this principle it is possible to drive off the whitewash by finishing the burn under reducing conditions. This has the disadvantage of darkening the color of the brick and also causing the slagging of the iron into a ferrous silicate, thus starting fusion prematurely.

"6. Coat the brick with some combustible substance that will remove the whitewash as it burns off. A method in vogue in Germany is to coat the brick on the face, as they leave the machine, with coal tar or wheat flour. As this burns away it has a strong reducing action and removes the whitewash as just explained."

DEFECTS OF STRUCTURE.

LAMINATIONS.

The laminations often occurring in stiff-mud brick are produced by the auger. The clay as it is forced over the smooth surface of the auger receives polished surfaces which may have failed to adhere perfectly when the clay is forced through the die. Then there is a differential movement of the clay through the die. The clay in the center of the die moves faster than at the sides because of the friction of the clay against the walls of the die. This differential movement also tends to increase laminations. This form of imperfection is more pronounced in plastic clays. If the bonding power of the clay is adequate, non-plastic material may be added to remedy the defect. The laminations may not be perceptible when the brick are first taken from the machine. During the process of drying the moisture will escape more freely along the lines of the laminations and the differential shrinkage so produced causes the "shells" of clay to separate.

Repressing, while not always completely destroying laminations, may greatly improve the quality of the brick.

GRANULATIONS.

There is a tendency for certain plastic clays to granulate in the grinding process. Instead of forming a dust-like powder, they roll up into shot-like grains. If the clay is mixed with water these granules may be destroyed. If, however the clay is used in the dry-press methods of molding, the granules are not destroyed in the process of molding and may cause an imperfect product. In the burning of the clay these granules may not unite unless the temperature of the brick is raised to the point of vitrification when the granules soften and unite. When the brick are not brought to this degree of temperature, incipient fusion of the outer side of the brick may cause a union of the granules, while the granules upon the inside are but indifferently united. The cross-breaking strength and the tensile strength of such a brick are very much impaired.

One remedy would be to insure absolutely dry conditions of the clay before grinding. Use a fine-mesh screen to eliminate larger granules, or mix thoroughly with a clay of lower fusibility.

SERRATIONS.

In the manufacture of stiff-mud brick the edges of the bars of clay are sometimes serrated as they come from the die. The serrations are caused by friction of the bar against the corners of the die. The same amount of friction may cause serrations in one clay and not in another. The bonding power of the latter is greater than that of the former. The friction between the bar and the clay may be partly overcome by the use of oil, steam or soap suds. Sometimes brick coming from the die contain serrations which are not very noticeable, but develop during drying. Repressing will in a large measure overcome serrations in brick.

BRITTLENESS.

Brittleness in brick is caused by too rapid cooling. After a kiln of hard brick is burned, it ought to be closed up and allowed to cool gradually. Gradual cooling toughens the brick and prevents brittleness. Clay conducts the heat so slowly that if the brick are cooled too rapidly internal stresses are set up which rupture them. Hard brick usually require from six to nine days for cooling. Wheeler thinks that far better results would be obtained by allowing twice that amount of time for cooling.

CHAPTER VIII.

GEOLOGY OF MISSISSIPPI CLAYS.

The following table shows the geological formations represented in the State, the oldest rocks being at the bottom and the youngest at the top.

GEOLOGICAL FORMATIONS OF MISSISSIPPI.

Cenozoic	Quaternary		Recent deposits.
			Columbia.
			Loess.
			Natchez.
			Lafayette.
	Tertiary	Miocene?—Grand Gulf.	
		Oligiocene—Vicksburg.	
		Eocene	Jackson.
			Claiborne.
			Wilcox.
			Midway.
Mesozoic	Cretaceous		Ripley.
			Selma chalk.
			Eutaw (Tombigbee).
			Tuscaloosa.
Paleozoic	Sub-carboniferous (Mississippian).		
	Devonian.		

PALEOZOIC.

DEVONIAN.

The oldest rocks of the State are of Devonian age. They form an outcrop along the western bank of the Tennessee River and along the lower courses of some of its small tributaries in Tishomingo County.

The rocks of these exposures consist of dark blue limestones with an over-burden of fossiliferous cherts and shales. The underlying rocks, as shown by well records, consist of limestones, sandstones and shales.

SUB-CARBONIFEROUS (MISSISSIPPIAN).

The rocks of the sub-carboniferous consist of limestones, cherts, shales and sandstones. They are of marine deposition and overlie the Devonian rocks. Exposures of the rocks are numerous along the courses of Big Bear Creek and other streams in the eastern part of Tishomingo and Itawamba Counties. In some places the chert layer has disintegrated into a very fine white silicious powder (tripoli) having the following composition:

TABLE 27.

ANALYSIS OF TRIPOLI FROM THE SUB-CARBONIFEROUS NEAR EASTPORT.

Constituent	*Per cent*
Moisture (H_2O)	0.20
Volatile matter (CO_2 etc.)	0.41
Silicon dioxide (SiO_2)	97.23
Iron oxide (Fe_2O_3)	0.60
Aluminum oxide (Al_2O_3)	0.30
Calcium oxide (CaO)	0.45
Magnesium oxide (MgO)	0.54
Sulphur trioxide (SO_3)	0.20
Total	99.93

Near Bear Creek, on the Candler place, a mine has been opened in tripoli, where the bed has a thickness of 15 or 20 feet. The overburden consists of cherts with partings of tripoli. The mine is not now in operation.

The limestone which underlies the chert and outcrops in the bed of a creek at old Eastport is blue to gray in color and occurs in layers varying from 12 to 15 inches. The chemical properties are given in the analysis below.

TABLE 28.

ANALYSIS OF EASTPORT LIMESTONE.

Constituent	*Per cent*
Moisture (H_2O)	0.40
Volatile matter (CO_2 etc.)	5.06
Silicon dioxide (SiO_2)	43.18
Iron oxide (Fe_2O_3)	3.13
Aluminum oxide (Al_2O_3)	3.43
Calcium oxide (CaO)	39.47
Magnesium oxide (MgO)	3.19
Sulphur trioxide (SO_3)	2.23
Total	100.09

A sample of blue limestone belonging to the sub-carboniferous formation was taken from a ledge having a thickness of 6 feet at Cypress Pond near Mingo. This is a compact, hard blue limestone with a chemical composition as recorded below. It lies above the cherts mentioned above.

TABLE 29.

ANALYSIS OF CYPRESS POND LIMESTONE.

Constituent	*Per cent*
Moisture (H_2O)	1.10
Volatile matter (CO_2 etc.)	27.00
Silicon dioxide (SiO_2)	10.91
Iron oxide (Fe_2O_3)	5.00
Aluminum oxide (Al_2O_3)	8.71
Calcium oxide (CaO)	47.06
Magnesium oxide (MgO)	0.16
Sulphur trioxide (SO_3)	0.85
Total	100.25

At Mingo Bridge on Bear Creek the following section of sub-carboniferous rock are exposed:

1. Black shale containing lenticular masses of claystone	12 feet
2. Limestone containing a large number of fossils	5 "

The shale in No. 1 weathers into thin plates and the carbonate of iron is oxidized, producing a red coloration. The chemical composition is given below.

TABLE 30.

ANALYSIS OF MINGO SHALE.

Constituent	*Per cent*
Moisture (H_2O)	2.30
Volatile matter (CO_2 etc.)	13.30
Silicon dioxide (SiO_2)	54.46
Iron oxide (Fe_2O_3)	12.50
Aluminum oxide (Al_2O_3)	14.92
Calcium oxide (CaO)	2.56
Magnesium oxide (MgO)	0.00
Sulphur trioxide (SO_3)	0.85
Total	100.89

MESOZOIC.

CRETACEOUS.

Tuscaloosa.—The rocks of the Tuscaloosa formation in Mississippi consist of basal gravels, laminated clays and gray sands. Beds of lignite also occur in the formation. Many of the clays are white and extremely aluminous in composition. Some of the clays are stained with an oxide of iron to such an extent as to form an ochre. The composition of a sample from R. F. Thorne's place, 6 miles north of Iuka, is given below:

TABLE 31.

ANALYSIS OF OCHEROUS CLAY FROM THE TUSCALOOSA, SIX MILES NORTH OF IUKA.

Constituent	*Per cent*
Moisture (H_2O)	0.87
Volatile matter (CO_2 etc.)	11.96
Silicon dioxide (SiO_2)	38.11
Iron oxide (Fe_2O_3)	11.73
Aluminum oxide (Al_2O_3)	36.42
Calcium oxide (CaO)	0.60
Magnesium oxide (MgO)	0.14
Sulphur trioxide (SO_3)	trace
Total	99.82

At Penniwinkle Hill, about 4 miles south of Iuka, the following geological section is exposed:

Section at Penniwinkle Hill.

	Feet
Blue micaceous clay weathering to yellow (top)	5
Gray, laminated, micaceous clay with thin ironstone layers	20
White, unlaminated but jointed clay	15

The first bed from the top probably forms a transition to the Lafayette which lies on the crest of the hill. The clay at the base is probably Tuscaloosa, though its determination is based entirely on stratigraphic conditions. The chemical composition of a sample of the clay from the white layer at the base is as follows:

TABLE 32.

ANALYSIS OF CLAY FROM PENNIWINKLE HILL.

Constituent	*Per cent*
Moisture (H_2O)	1.09
Volatile matter (CO_2 etc.)	7.34
Silicon dioxide (SiO_2)	68.65
Iron oxide (Fe_2O_3)	2.77
Aluminum oxide (Al_2O_3)	18.99
Calcium oxide (CaO)	.20
Magnesium oxide (MgO)	.20
Sulphur trioxide (SO_3)	trace
Total	99.24

PLATE XXII.

EUTAW SANDS ON TOMBIGBEE RIVER, COLUMBUS.

Some of the white clays of the Tuscaloosa formation contain a large quantity of tripoli from the subcarboniferous. Its white color and extreme fineness of grain conceal its presence from ordinary observation, but chemical determinations reveal it. The following table of analyses gives the chemical properties of a number of these clays:

TABLE 33.

ANALYSES OF TUSCALOOSA CLAYS FROM TISHOMINGO COUNTY.

	No. 1	*No.* 2	*No.* 3	*No.* 4	*No.* 5	*No.* 6	*No.* 7
Moisture (H_2O)........	.58	.58	.48	.59	1.18	.48	1.11
Volatile matter (CO_2)..	5.20	4.78	4.82	8.00	6.39	15.01	13.88
Silicon dioxide (SiO_2).	70.81	79.23	80.03	66.85	71.03	44.23	42.92
Iron oxide (Fe_2O_3).....	11.20	.67	1.68	3.77	.56	.81	.61
Aluminum oxide(Al_2O_3)	11.20	13.91	12.00	20.54	20.29	38.82	41.30
Calcium oxide (CaO)..	.60	.59	.26	.21	.20	.19	.37
Magnesium oxide(MgO)	.50	.21	.00	.18	.13	.13	.13
Sulphur trioxide(SO_3).	trace	trace	trace	trace	.25	.45	.18
Total............	100.09	99.97	99.27	100.14	99.98	100.12	100.57

Clay No. 1 is from the public road near the fish pond at Iuka. No. 2 is from the public road 2 miles south of Old Eastport. No. 3 is from the R. W. Peden farm, and No. 4 is from the Jas. Turner farm. Nos. 5, 6 and 7 were collected by Dr. F. T. Carmack from near Tishomingo city.

Eutaw (*Tombigbee*).—The Eutaw formation consists of greenish colored sands containing, in some localities, indurated layers of irregularly bedded sandstones, and in other places thin laminæ of clay. The sands are micaceous and contain some calcareous matter which increases in amount toward the upper horizon where it passes by a gradual transition into the overlying Selma chalk. The upper beds are abundantly fossiliferous. The lower beds are less fossiliferous and contain irregular masses of indurated materials and lenticular bodies of iron sulphide. Lignite and lignitic clays are not of infrequent occurrence in the lower beds.

Typical exposures of the fossiliferous strata are to be found along the bluffs of the Tombigbee River from Amory to Columbus. The river, sinking its channel into the soft rocks of the Eutaw, traces the western boundary of the formation across the northeastern part of the State. The Eutaw forms the chief water-bearing stratum for the northeastern prairie belt, and its collecting ground is along the Tombigbee River basin.

Selma Chalk (*rotten limestone*).—The rock of the Selma chalk is for the most part a fine-grained cretaceous limestone. On unweathered surfaces it has a bluish tint; on weathered areas it is white in color. Thin layers of crinoidal limestone and lenticular sandstone masses are occasionally encountered. Thin seams of asphaltum and nodular forms of iron pyrites occur in some outcrops. The amount of calcium carbonate in the formation varies, but in general it increases toward the southern portion of the area. The thickness also increases toward the south, being about 75 feet at the northern line of the State and reaching a thickness of about 1,000 feet near its southern limit.

The transition from the underlying arenaceous Eutaw to the highly calcareous Selma is gradual, so that the lowermost bed of the latter contains a large percentage of sand and a correspondingly small amount of calcium carbonate. Both vertically and horizontally the chalk varies in the amount of clay which it contains. In some places the formation contains as much as 16 per cent of alumina. The white rock, the weathered product of the blue, naturally contains more clay than the unweathered rock, since some of the calcium carbonate has been removed during the process of weathering and the insoluble aluminum silicate left behind.

TABLE 34.

ANALYSES OF SELMA CHALK.

	No. 1	*No.* 2	*No.* 3	*No.* 4	*No.* 5	*No* 6
Moisture (H_2O)	1.10	.94	1.08	.40	1.50	2.75
Volatile matter (CO_2)	34.20	42.05	27.10	25.60	24.50	22.61
Silicon dioxide (SiO_2)	18.70	9.84	14.84	25.27	29.98	32.81
Iron oxide (Fe_2O_3)	6.00	2.58	4.50	10.35	5.60	4.65
Aluminum oxide (Al_2O_3)	.00	.19	15.59	4.81	5.45	11.15
Calcium oxide (CaO)	45.62	38.65	32.89	32.85	31.62	22.69
Magnesium oxide (MgO)	1.72	.18	.41	.84	.14	1.53
Sulphur trioxide (SO_3)	1.11	2.05	3.30	.32	.21	1.55
Total	98.45	96.48	99.71	100.64	99.02	99.74

Sample No. 1 is from Okolona, Chickasaw County; Nos. 2, 4 and 5 are from Oktibbeha County; No. 3 is from Tupelo, Lee County, and No. 6 is from West Point, Clay County. The majority of these samples contain clay, the per cent ranging from .48 to 39.44. They also contain some sand. The greater number of these samples were taken from the surface of the limestone where weathering processes have caused a considerable loss of calcium carbonate. Some unweathered specimens of chalk have exhibited more than 90 per cent of lime. The weathering of the limestone has produced the main supply of brick clay of the Selma area.

Ripley.—Overlying the Selma chalk and bordering the northwestern portion of its outcrop are the marls of the Ripley. In some places the chief component of the marl is clay. They are generally highly fossiliferous and greenish in color, due to the presence of glauconite. In some exposures there are thinly bedded arenaceous limestones. The composition of one of these arenaceous rocks from Tippah County is given below.

TABLE 35.

ANALYSIS OF RIPLEY SANDSTONE.

Moisture (H_2O)	3.94
Volatile matter (CO_2)	1.82
Silicon dioxide (SiO_2)	82.95
Iron oxide (Fe_2O_3)	6.50
Aluminum oxide (Al_2O_3)	.87
Calcium oxide (CaO)	2.00
Magnesium oxide (MgO)	.54
Sulphur trioxide (SO_3)	.60
Total	99.22

Near the old mill in the northern part of the town of Ripley the following section is exposed:

Section of Ripley in the Town of Ripley.

	Feet
4. Yellow to brown loam	4
3. Gray clay	3
2. White shally rock	2
1. Fossiliferous green sand	10

The gray clay from No. 3 has the chemical composition recorded in the following analysis:

TABLE 36.

ANALYSIS OF CLAY, RIPLEY.

Moisture (H_2O)	8.23
Volatile matter (CO_2 etc.)	3.96
Silicon dioxide (SiO_2)	67.10
Iron oxide (Fe_2O_3)	6.60
Aluminum oxide (Al_2O_3)	10.96
Calcium oxide (CaO)	1.87
Magnesium oxide (MgO)	.54
Sulphur trioxide (SO_3)	.51
Total	99.77

CENOZOIC.

TERTIARY.

Eocene.

The eocene of Mississippi is composed of the following stages: Midway, Wilcox, Claiborne and Jackson.

Midway.—The Midway is composed of two formations, the Clayton limestones and the Porter's Creek (Flatwoods) clays. The latter are gray laminated and somewhat shaly clays. Some of the lowermost beds contain small white concretions of irregular shape and usually of small size. In the upper beds, layers of ironstone concretions abound. These are usually lens-shaped masses; some are irregular in form. Occasionally the lens-like masses form a continuous layer which persists for several rods. The clay is frequently micaceous. It is exceedingly fine-grained and highly silicious, containing as much as 70 per cent of silicon dioxide. The Flatwoods clay is exceedingly sticky and the wagon roads across its outcrop are kept in condition with great difficulty. Though of highly silicious character, the grains of silica are exceedingly small so that they are not detected by ordinary methods of observation.

The following table shows the analyses of some samples of the Flatwoods clays:

TABLE 37.

ANALYSES OF FLATWOOD CLAYS.

	No. 1	*No.* 2	*No.* 3	*No.* 4
Moisture (H_2O)	2.97	4.50	5.65	4.95
Volatile matter (CO_2 etc.)	3.91	7.77	5.04	9.05
Silicon dioxide (SiO_2)	75.60	61.62	71.47	65.60
Iron oxide (Fe_2O_3)	8.24	15.29	6.97	7.20
Aluminum oxide (Al_2O_3)	7.00	.87	9.45	10.50
Calcium oxide (CaO)	1.20	.81	.40	1.12
Magnesium oxide (MgO)	.67	.69	.63	.60
Total	99.84	99.83	99.74	99.98

Clays Nos. 1 and 4 are from Oktibbeha County; No. 2 is from Winston County, and No. 3 is from Noxubee County.

Wilcox (*Lagrange*).—The Wilcox formation consists of sands and clays with intercalated beds of lignite. The sands are for the most part unconsolidated sediments, though occasionally irregular masses of sandstone or ironstone appear in the outcrops of its strata. The sands are very much cross-bedded and inter-bedded with thin seams of clay. The colors are variegated. In many places, thick beds of pink or white pottery clays are present.

In the upper portion of the formation there are beds of shale-like clay of a dark color. The clays have a low specific gravity and are fine in grain.

There is an outcrop of these clays in the bank of the Yalobusha River, at Grenada. The bed has a thickness of about 40 feet. The chemical composition of a sample of the clay is given below:

TABLE 38.

ANALYSIS OF WILCOX CLAY, GRENADA.

Moisture (H_2O)	5.91
Volatile matter (CO_2)	8.75
Silicon dioxide (SiO_2)	61.80
Iron oxide (Fe_2O_3)	3.88
Aluminum oxide (Al_2O_3)	16.50
Calcium oxide (CaO)	1.00
Magnesium oxide (MgO)	.23
Sulphur trioxide (SO_3)	.19
Total	98.26

The pink and the white clays of the lower and middle horizons of the Wilcox are used in a number of counties in the manufacture of stoneware. The following table gives the analyses of some of the pottery clays:

TABLE 39.

ANALYSES OF WILCOX POTTERY CLAYS.

	No. 1	*No.* 2	*No.* 3	*No.* 4	*No.* 5	*No.* 6
Moisture (H_2O)	.66	1.84	1.92	.62	.23	1.47
Volatile matter (CO_2 etc.)	7.25	8.23	7.66	7.02	4.81	9.24
Silicon dioxide (SiO_2)	62.41	60.78	63.56	64.86	75.78	59.82
Iron oxide (Fe_2O_3)	2.80	3.52	2.83	4.19	3.56	1.26
Aluminum oxide (Al_2O_3)	24.02	24.12	21.92	20.70	14.11	27.19
Calcium oxide (CaO)	.57	.73	.48	.69	.54	.49
Magnesium oxide (MgO)	.50	.38	.62	.59	.52	.37
Sulphur trioxide (SO_3)	.56	.38	.28	trace	.00	.31
Total	98.97	99.98	99.29	98.67	99.55	100.15

Clays Nos. 1, 2 and 3 are from Marshall County; Nos. 4 and 5 are from Lafayette County; No. 6 is from Webster County.

Claiborne.—The rocks of the Claiborne are divided into Tallahatta buhrstone (Siliceous Claiborne), Lisbon, and the undifferentiated Claiborne.

The Tallahatta buhrstone is composed of hard white quartz rocks with impure calcareous sandstones and claystones. In some localities the formation consists of ferruginous sands, but slightly cemented and containing numerous fossils. In other localities the sandstones are cherty in character, with thin layers inter-bedded with sandy clays. The white quartz rock constitutes one of our best road metals. Unfortunately very little of it has been used in this State. During 1906, 100 carloads were shipped from West to Louisiana to be used in street pavement work.

The Lisbon is composed of white sands containing calcareous material, greenish marls, and lignitic clays. The calcareous beds are highly fossiliferous. Species of the genera Ostrea and Pecten are the most abundant fossils. Between the Lisbon beds and the Jackson formation is a great thickness of undifferentiated Claiborne.

Jackson.—The Jackson formation is composed of clays, marls and sands. The clays in some outcrops contain the bones of Zeuglodon, an extinct marine animal of huge size. Aggregates of selenite crystals are abundant in some layers. The marls are very generally fossiliferous. The sands are sometimes interbedded with lignitic clays or lignite.

The outcrop of the Jackson and the Vicksburg forms the central prairie belt of the State.

At Morton, there is an exposure of the upper Jackson beds which has the following stratigraphy:

Section of Upper Jackson Beds at Morton.

	Feet
5. Grayish clay in thin layers	5
4. Lignite and lignitic clay	6
3. White sand with clay partings	15

And at a lower level:

	Feet
2. Layers of yellow sand and gray clay	20
1. Gray clay	6

On the south side of the ridge where the above-mentioned exposure occurs, the following section is exposed:

3. Orange sand with gravel and ironstone (Lafayette).
2. Clay with purple clay stones (Grand Gulf?).
1. Gray laminated clay with selenite crystals (Jackson).

At Barnett, a yellow laminated clay streaked with blue has a thickness of at least 25 feet. The clay contains crystals of selenite and fossils. It has the following chemical properties:

TABLE 40.

ANALYSIS OF BARNETT CLAY.

Moisture (H_2O)	5.55
Volatile matter (CO_2 etc.)	13.80
Silicon dioxide (SiO_2)	38.75
Aluminum oxide (Al_2O_3)	22.83
Iron oxide (Fe_2O_3)	3.14
Calcium oxide (CaO)	14.25
Magnesium oxide (MgO)	1.01
Sulphur trioxide (SO_3)	trace
Total	99.33

Oligocene.

Vicksburg.—The line of outcrop of the Vicksburg parallels the Jackson on the South. Its rocks are limestones and marls. Typical exposures occur in the bluffs of the river at Vicksburg. In the exposures along the river front, there are five or six layers of limestone interbedded with marl and clay. They overlie dark colored clays and sands. The limestone varies in thickness in the different ledges and even in the same ledge. The individual layers are from 1 to 6 feet thick. The following table gives the chemical composition of Vicksburg limestone from a number of exposures:

TABLE 41.

ANALYSES OF VICKSBURG LIMESTONE.

	No. 1	*No.* 2	*No* 3	*No.* 4
Moisture (H_2O)	.40	1.00	1.79	2.10
Volatile matter (CO_2 etc.)	37.22	35.20	35.40	33.16
Silicon dioxide (SiO_2)	7.08	7.31	6.77	14.88
Iron oxide (Fe_2O_3)	2.50	4.00	2.00	3.59
Aluminum oxide (Al_2O_3)	.61	13.66	4.68	5.70
Calcium oxide (CaO)	50.44	36.62	45.51	36.86
Magnesium oxide (MgO)	1.07	.29	.64	.99
Sulphur trioxide (SO_3)	.38	2.78	3.00	.24
Total	99.70	100.86	99.79	97.72

Sample No. 1 is from Warren County; No. 2 and No. 3 are from Wayne County, and No. 4 is from Rankin County.

At Brandon, in Rankin County, there are some excellent exposures of Vicksburg limestone. On the Robinson place, 4 miles southeast of Brandon, there is a stone quarry in which six layers of limestone are found interbedded with marl in the following stratigraphic order:

Section of Vicksburg at Robinson Quarry, near Brandon.

	Feet
13. Soil and decomposed rock	2
12. Limestone	1–1½
11. Marl	1
10. Limestone	2
9. Marl	2
8. Limestone	1¼
7. Marl	1½
6. Limestone	1½–2
5. Marl	2
4. Limestone	2
3. Marl	1¼
2. Limestone	2
1. Marl	2

The limestone is bluish on fresh fractures but weathers white. It is fossiliferous, containing abundant evidence of marine life.

Miocene.

Grand Gulf.—In Mississippi, the Grand Gulf formation is made up of gray, clayey sandstones, white quartz rocks and clays. The latter contain considerable organic matter and are of a dark color in many areas. The Pascagoula is thought by some to be a part of the Grand Gulf. Samples of silicious claystones of the Grand Gulf have been analyzed with the following results:

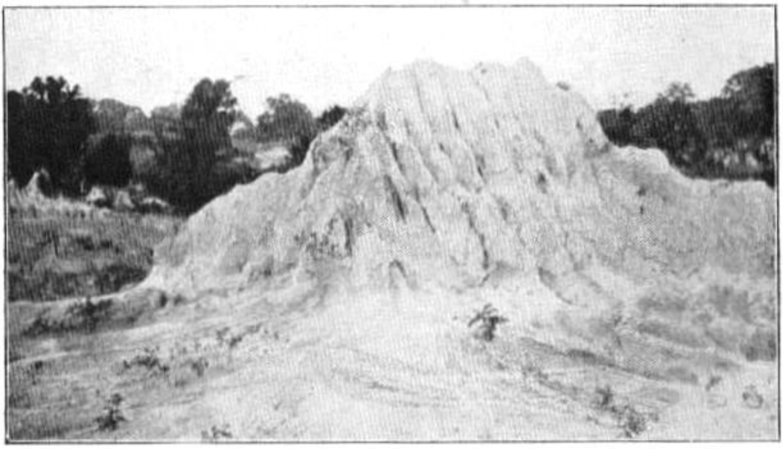
TABLE 42.

ANALYSES OF GRAND GULF CLAYSTONES.

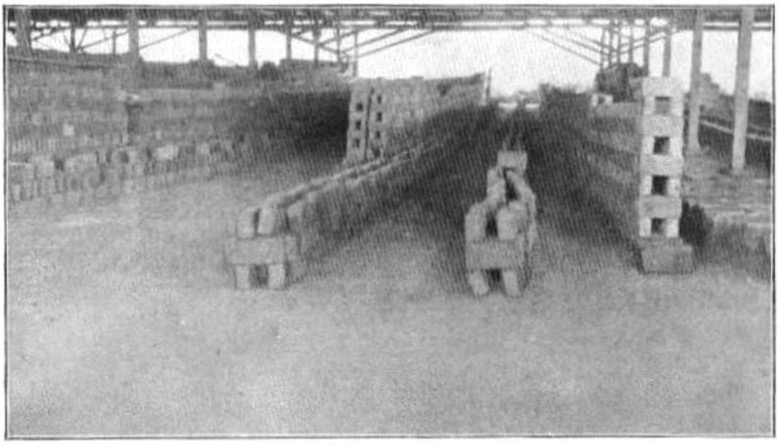
	Per cent			
	No. 1	*No. 2*	*No. 3*	*No. 4*
Moisture (H_2O)	3.59	.74	.75	.50
Volatile matter (CO_2 etc.)	2.93	1.51	3.50	.38
Silicon dioxide (SiO_2)	77.44	92.13	81.85	88.11
Iron oxide (Fe_2O_3)	4.17	1.61	3.00	4.00
Aluminum oxide (Al_2O_3)	11.09	2.96	8.32	5.81
Calcium oxide (CaO)	.53	.54	.82	.56
Magnesium oxide (MgO)	.31	.42	.00	.00
Sulphur trioxide (SO_3)	.05	.05	2.84	1.50
Total	100.11	99.96	101.08	100.86

Some beds of the Grand Gulf formation are composed of clear quartz grains cemented together with a silicious cement so that they present the appearance and hardness of quartzites. White chalk-like clays occur in some localities.

PLATE XXIII.



A. DENUDATION IN LAFAYETTE AFTER DEFORESTING, BRANDON.



B. SOFT-MUD BRICK HACKED UNDERED COVER SHED.

The table given below contains the analyses of some of the Grand Gulf clays:

TABLE 43.

ANALYSES OF GRAND GULF CLAYS.

	No. 1	*No. 2*	*No. 3*	*No. 4*
Moisture (H_2O)	.60	2.36	3.65	1.09
Volatile matter (CO_2 etc.)	5.10	4.01	1.16	2.98
Silicon dioxide (SiO_2)	72.32	74.92	68.28	82.42
Iron oxide (Fe_2O_3)	3.00	2.96	10.00	2.40
Aluminum oxide (Al_2O_3)	15.81	13.25	1.76	9.65
Calcium oxide (CaO)	.47	.20	.87	.70
Magnesium oxide (MgO)	trace	.38	.76	.46
Sulphur trioxide (SO_3)	2.75	2.12	4.26	.12
Total	100.05	100.20	90.14	99.62

Nos. 1, 2 and 4 are from Jefferson County and No. 3 is from Warren County.

QUATERNARY.

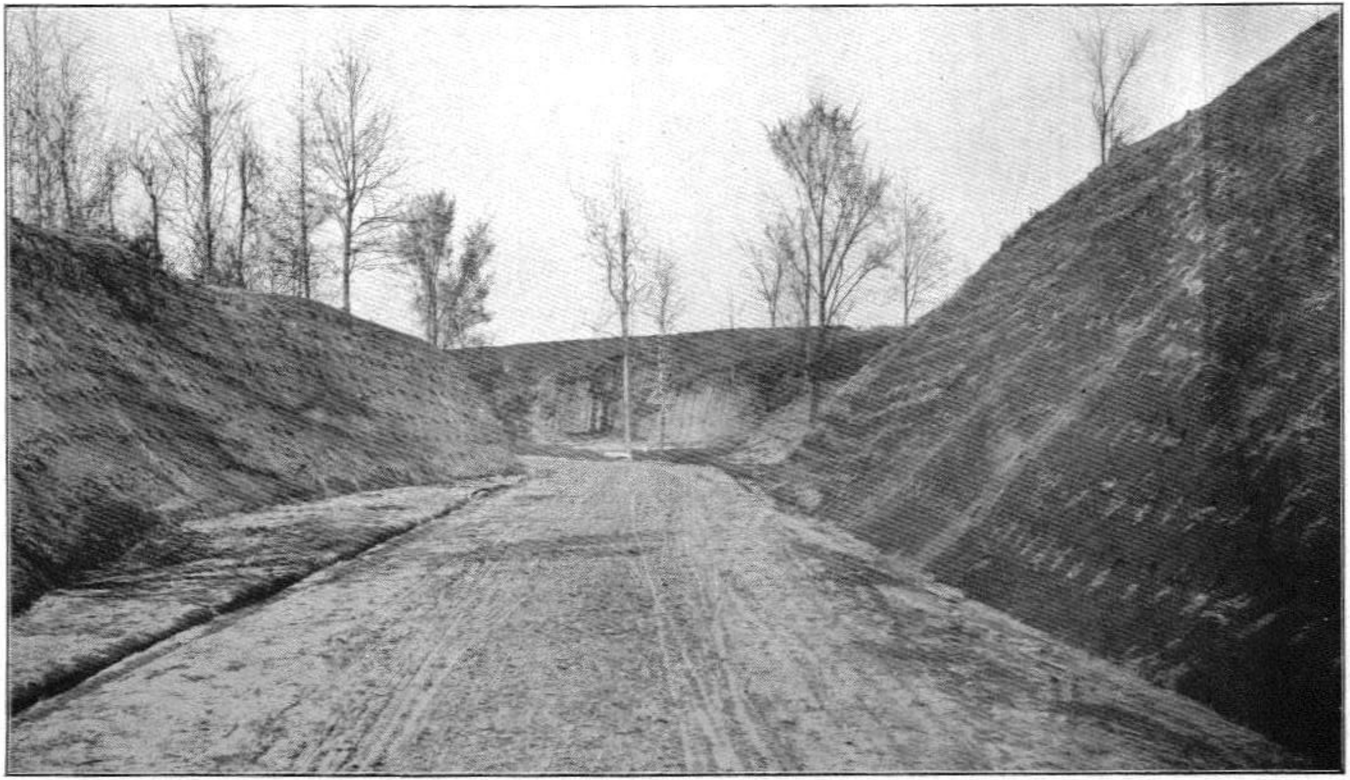
Lafayette.—The rocks of the Lafayette consist of sands, gravels, conglomerates, ironstones, loams and plastic clays. It is one of the most widely distributed formations in the State occupying practically all of the surface of the higher lands. Bright coloring is characteristic of nearly every outcrop. Orange, purple, pink, yellow, buff and white colored sands and clays occur in a great diversity of stratigraphic relationships. Blotched and mottled surfaces abruptly changing from one color to another are common. The prevailing coloration is largely due to the presence of ferric iron.

The thickness of the formation rarely exceeds 50 feet. The stratigraphic appearance of many of the sands is so suggestive of dune deposition that the conclusion that they are of eolian origin would seem irresistible but for the presence of "pebble" clay. The shape, mass, and distribution of this is not in harmony with such a view.

Three modes of origin have been suggested for the Lafayette. First, the glacio-fluvial hypothesis suggested by Hilgard in a Report on the Agriculture and Geology of Mississippi, published in 1860. Second, the marine deposition hypothesis, published by McGee in Twelfth Annual Report of the United States Geological Survey. Third, the Aggradation hypothesis, suggested by Chamberlin and Salisbury in Earth History, Vol. III, pp. 305–307. The statement of the last hypothesis is given in the words of the authors: "As here interpreted, the Lafayette formation belongs to an important class, long neglected, but now coming into recognition, whose distinctive features are less critically familiar than those of marine, lacustrine, and typical fluvatile formations. The preferred interpretation is as follows: After the Cretaceous base-leveling of the region, the Appalachian tract was bowed up and a new stage of degradation inaugurated. During the long Eocene period, a partial peneplaining of the less resistant tracts was accomplished. This was slightly interrupted by the Oligiocene deformation, and the streams mildly rejuvenated in the more responsive tracts. During the Miocene period, base-leveling was resumed, abetted by relative subsidence along shore, as indicated by the landward spread of the Miocene sea, and the open low grade valleys and abundant low cols of the region west of the Appalachians, if the interpretation here given be correct. At the opening of the Pliocene, therefore, the Appalachian tract is supposed to have been affected by broad, flat, intermontane valleys, mantled by a deep layer of residual decomposition products. The Piedmont tract skirting the Appalachians is supposed to have been flanked on the seaward side by a peneplain near sea level, and on the other side by broad, open valleys of low gradient. It is assumed that the upward bowing was felt first in a relatively narrow belt along the predetermined axis, that the rise was gradual, and that the rising arch increased its breadth as it rose. The first bowing along the axis rejuvenated the head waters of the streams which reached it, and the surface, deeply mantled with residuum accumulated during the peneplaining stage, readily furnished load to the streams in flood stages. When the streams reached that portion of the peneplain not yet affected by the bowing, they found themselves loaded beyond their competency, and gave up part of their load. Thus arose a zone of deposition along the bowed tract, with continued rise, the mountainward border of the depositional zone is supposed to have been shifted seaward, and the previous border elevated and subjected to erosion, while the material removed was re-deposited in a new zone farther from the axis of rise.

"Thus the process is presumed to have continued till the border of the lifted tract passed beyond the present seacoast, after which the whole mantle was subjected to erosion, which has reached a notable degree of advancement before the first known glacio-fluvial deposits were laid down."

PLATE XXIV.



SODDING LOESS SLOPES WITH BERMUDA GRASS AS A PROTECTION AGAINST EROSION, NATIONAL PARK, VICKSBURG.

Natchez.—The Natchez formation has its typical development at Natchez, where the thickness assigned is 200 feet. It rests erosively unconformable upon the Lafayette. The formation is composed of sands and gravels containing calcareous clays. According to Chamberlin, its age is either sub-Aftonian or Aftonian. (See Earth History, Vol. III, pp. 386–8.)

Loess (*Bluff Formation*).—A fine silty material of brownish color containing concretions and tubules of lime carbonate and shells of species of gastropods is called the Loess. In thickness, it varies from a few feet to a hundred or more.

The Loess is thought to be a deposit formed largely by winds, which transported silt and rock flour from the flood plains of rivers and from over-washed plains during glacial or inter-glacial epochs.

In Mississippi the Loess occupies a tract along the eastern border of the Mississippi Valley. The tract is narrow and the thickest part of the deposit is upon the immediate banks of the valley and thins rapidly toward the east. In the majority of places the upper surface is occupied by a bed of residual clay, having a thickness of 6 to 10 feet, and much used for brick clay.

Columbia.—The brown and yellow loams which occupy the surface of practically all the hill country of the State have been assigned to the Columbia. In point of time these loams represent in some instances doubtless all of the time which has elapsed since the Lafayette deposition. In other instances only that time which has elapsed since the deposition of the Loess.

The time which has elapsed since the deposition of the Lafayette has permitted the accumulation of various surficial deposits of clay, sand and loam. These have resulted in a large measure from the disintegration and decomposition of older formations. That the formation is largely residual is not to be denied. That it is composed partly of transported material is within the bounds of reasonable probability. That such transported material is largely of Eolian origin is also very probable.

The brown loam and clay which rest upon the Loess is without doubt a residual product of the latter's decomposition. It is probable that the loams are for the most part only modified forms of the Loess. The Loess thins out and loses its identity a short distance from the

Mississippi bluffs. The loams, however, cover the whole State except where they have been removed by erosion.

Recent Deposits.—The recent deposits consist of undifferentiated loams of the hill country, the alluvial deposits of the flood plains, and recent deposits along the coast, some of which are marine, others lacustrine and others estuarine.

The largest area of recent deposits is that of the Yazoo basin. This basin is a flood plain area between the Yazoo River and the Mississippi River. The rocks, sands, clays and silts have been deposited by the streams.

The flood plain material is of two kinds. First, the sandy loam which is found along the courses of the streams. Following the law of deposition, when a stream carrying sediment overflows its banks the water begins to lose its velocity and to deposit the coarser, heavier particles of its suspended matter near the streams. Second, the finer clayey materials which are found on the inter-stream areas. According to the same law of deposition, the finer particles are carried longer in suspension and are dropped farther from the main channel. Frequently coarse sediments are carried into the inter-stream areas by temporary currents set up during overflows. Therefore, layers of sandy loam are often interbedded with layers of plastic clay.

CHAPTER IX.

THE CLAYS AND CLAY INDUSTRIES OF NORTHERN MISSISSIPPI BY COUNTIES.

The following chapter contains a statement of our present knowledge of the clays and clay industries of the northern half of the State. The report is not complete and is only preliminary. The clay industries, like all other industries in the State, are developing so rapidly that the collector of statistics scarcely turns his back upon a field before new plants have sprung into existence. The following is a list of the counties wholly or partly included in the report:

Alcorn
Attala
Carroll
Clay
Chickasaw
Choctaw
Coahoma
De Soto
Grenada
Hinds
Holmes
Kemper
Lafayette
Lauderdale
Lee
Leflore
Lowndes
Madison
Marshall
Montgomery
Monroe
Newton
Noxubee
Oktibbeha
Panola
Pontotoc
Prentiss
Rankin
Scott
Sunflower
Tate
Tippah
Tunica
Union
Warren
Washington
Webster
Winston
Yalobusha
Yazoo

ALCORN COUNTY.

GEOLOGY.

The bed-rock of this county is formed of Cretaceous strata. The extreme southeastern corner of the county is underlain by the Tuscaloosa sands and clays. The eastern part of the county is underlain by the sands of the Eutaw (Tombigbee) group. The central portion of the county has for its subformation the Selma chalk, and the western portion is occupied by the Ripley. The principal mantle rock formations are the Lafayette sands and clays and the Columbia loams. There are also some residual deposits formed directly from the bed-rock formations. The Lafayette formation is represented by isolated outcrops. The Columbia loam has a wider distribution. In the Selma chalk area the soil often rests directly upon the chalk.

CLAY INDUSTRY.

Corinth.—The residual clay from the Selma is utilized in the county in the manufacture of brick. Lafayette sandy clay and the Columbia loams are used with the residual Selma, since the latter is generally too plastic. At Corinth, the residual clay of the Selma chalk and the Lafayette clay are used in the manufacture of brick by the Corinth Brick Manufacturing Co. In the pit the following stratigraphical conditions are revealed:

Section of the Pit of the Corinth Brick Mfg. Co., Corinth.

	Feet
4. Yellowish loam (Columbia)	3
3. Red sandy clay (Lafayette)	4
2. Plastic clay (residual Selma)	2–3
1. White chalk (Selma)	...

In the manufacture of brick a mixture of Nos. 2, 3 and 4 is used. The clay is prepared in a granulator and tempered in a pug mill. It is molded in a stiff-mud, end-cut machine. The brick are burned in rectangular, up-draft kilns of the clamp type.

A sample of clay taken from layer No. 2, upon analysis, gave the following results:

TABLE 44.

ANALYSIS OF RESIDUAL SELMA CLAY, CORINTH.

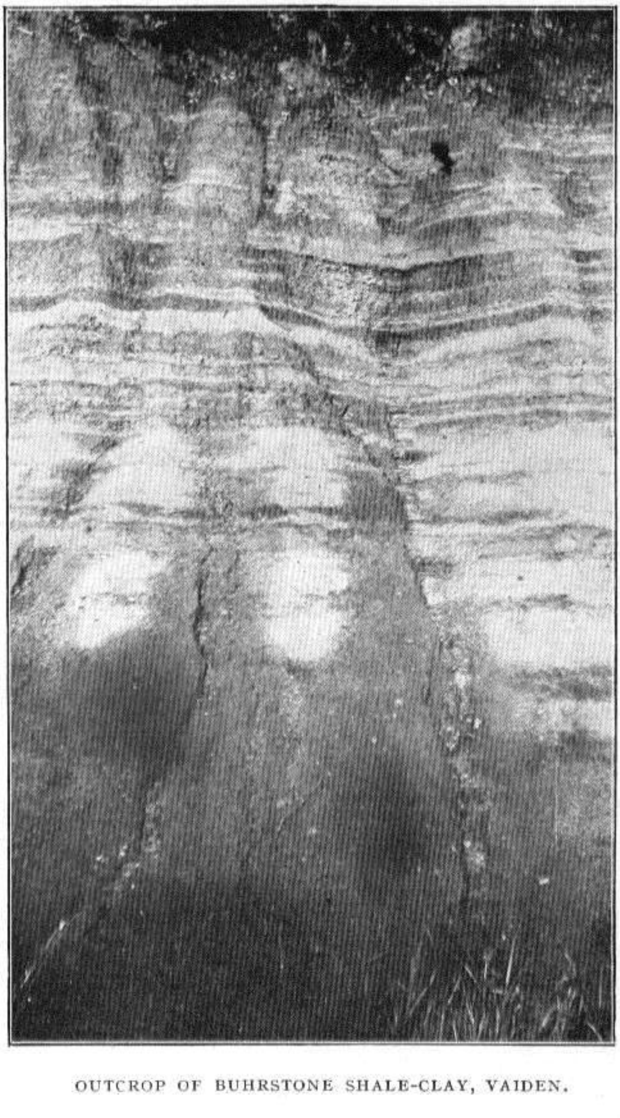
	No. 104
Moisture (H_2O)	3.85
Volatile matter (CO_2)	4.45
Silicon dioxide (SiO_2)	76.77
Iron oxide (Fe_2O_3)	6.25
Aluminum oxide (Al_2O_3)	8.56
Calcium oxide (CaO)	.31
Magnesium oxide (MgO)	.04
Sulphur trioxide (SO_3)	.00
Total	100.23

RATIONAL ANALYSIS.

Clay substance	21.65
Free silica	66.72
Impurities	6.60

A sample of the Selma chalk collected from this locality by A. F. Crider has the following chemical composition:

PLATE XXV.



OUTCROP OF BUHRSTONE SHALE-CLAY, VAIDEN.

TABLE 45.

ANALYSIS OF SELMA LIMESTONE, CORINTH.

Moisture (H_2O)	4.47
Volatile matter (CO_2 etc.)	23.70
Silicon dioxide (SiO_2)	25.40
Aluminum oxide (Al_2O_3)	6.88
Iron oxide (Fe_2O_3)	8.62
Calcium oxide (CaO)	26.37
Magnesium oxide (MgO)	.58
Sulphur trioxide (SO_3)	.64
Total	96.66

Clay from layer No. 2 of the above section contains 17.40 per cent of clay and some silica. It cannot be used alone in the manufacture of brick. The chief objections to its use are : (*a*) the large amount of soluble salts which it contains; (*b*) an excess of calcium carbonate; (*c*) high plasticity. The soluble salts are liable to produce kiln-white or wall-white, and calcium carbonate is liable to cause cracking of the ware, and the high plasticity may prevent successful drying except by extremely slow methods.

A sample of clay from layer No. 3 has the following physical properties: It requires 19 per cent of water to render it plastic. The tensile strength of its raw brickettes is 87 pounds per square inch; when burned it has a tensile strength of 150 pounds per square inch. The color of the burned brickettes is a deep red. The total shrinkage is only 2 per cent. The clay slakes very rapidly. This clay lacks sufficient plasticity for the stiff-mud process of molding. In connection with No. 4 it could be utilized in the manufacture of soft-mud brick.

No. 4 is a loam which is lacking in plasticity. It does not possess high enough bonding power to make good brick. A mixture of these three layers in the proper proportion is essential to a good stiff-mud product. To obtain the best results the clays should be crushed and thoroughly mixed before going to the molding machine. In case a large amount of clay from No. 2 is used, the brick ought to be carefully guarded from air currents for the first few hours after being taken from the machine.

Rienzi.—In 1906, Mr. J. D. Furtick of Rienzi was engaged in the manufacture of brick for local use. The brick were molded by the soft-mud process and burned in rectangular, up-draft scove kilns.

The pit from which the clay was taken has the following stratigraphy:

Section of Clay Pit, Rienzi.

	Feet
4. Soil	1
3. White "hard pan" fine sand	1
2. Yellowish clay (Columbia?)	10
1. Water bearing sand	...

Layer No. 2 is light gray in the upper portion and bluish in color in the lower portion. The grayish clay has a total shrinkage of 5 per cent. Its tensile strength in the raw state is 182 pounds. Hard-burned brickettes have a strength of 322 pounds. It requires 27 per cent of water to render it plastic. In passing from the stiff-mud to the burnt state it loses 33 per cent of its weight. The burned brickettes absorb 14.92 per cent of water. The white clay absorbs 26.66 per cent of water. A sample of No. 3 required 16 per cent of water to render it plastic. It has a total shrinkage of 2 per cent. In the raw state its tensile strength is only 45 pounds per square inch, and when burned only 30 pounds per square inch. It is composed of very fine silica, and lacks bonding power.

ATTALA COUNTY.

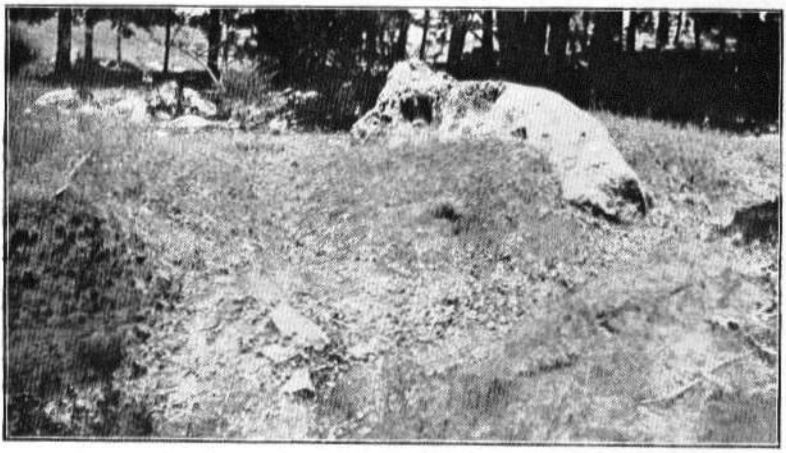
GEOLOGY.

Attala County lies partly within the Wilcox, but almost wholly within the Claiborne area. The surface formations are of Lafayette and Columbia age.

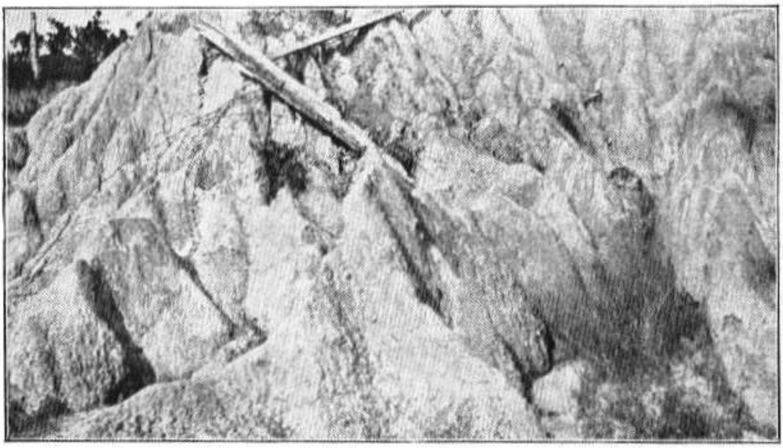
CLAY INDUSTRY.

Kosciusko.—The clay from the Columbia is used at Kosciusko in the manufacture of brick, in a plant operated by Storer and Miller. The plant was first established by A. M. Storer in 1902, and in 1906 the Storer and Miller Company was formed. The clay is tempered in a pug mill and molded in an end-cut stiff-mud machine. The kilns are up-draft clamp kilns of rectangular shape. The brick are dried on pallets in open covered racks.

The second bottom clays of the surface formations are, generally speaking, the best clays for the manufacture of stiff-mud brick. The Lafayette and Columbia loams of the higher lands may be used in the manufacture of soft-mud brick. The aluminous clays of the



A. QUARTZ BOWLDERS OF THE BUHRSTONE, NEAR WEST.



B. EROSION IN THE LAFAYETTE, VAIDEN.

Wilcox may be utilized in the manufacture of a light colored, dry-pressed brick. The white color can be varied by sprinkling the surface of the brick with iron or manganese to produce specks or spots in burning. These spotted brick make a very attractive ware.

CARROLL COUNTY.

GEOLOGY.

The strata of the Tallahatta buhrstone constitute the bed-rock of Carroll County. The rocks consist of clays, sands and quartzites. The clays are exposed in cuts and along the banks of the streams; the quartzites form the cap-rock for some of the inter-stream areas.

The mantle rock formations of the county are Lafayette, Loess, Columbia loam, and the alluvium of the Yazoo basin. In a railroad cut on the Illinois Central, south of the station at Vaiden, there are exposed about 30 feet of laminated clay belonging to the Claiborne. This clay is of a brownish-gray color, varying to purple and weathering to red or purple. The clay is interbedded with layers of very sandy white clay. It also contains thin wavy partings of limonite. In a small depression on the west side of the cut, a bad-land type of topography has been developed, and the following stratigraphic features are revealed:

Section near Vaiden.

	Feet
5. Soil	1
4. Brown loam	8
3. Reddish clay	10
2. Red and white mottled clay	10
1. Grayish clay	5

The reddish clay of No. 3 is probably Lafayette, though it has no gravel and is very similar to the residual clay of No. 1. The line of separation of No. 3 and No. 4 is more clearly marked by change in texture than by change in color. Wherever No. 4 has been completely removed by erosion, the exposed surface of No. 3 cracks into blocks of circular shapes. This is due to the high plasticity and excessive shrinkage of the clay. In some places No. 3 contains small flat ironstone concretions.

The clay from No. 1 requires 27 per cent of water for plasticity. It has a total shrinkage of 15 per cent. The raw clay brickettes have a tensile strength of 187 pounds per square inch. When burned, the tensile strength is 200 pounds per square inch. Absorption is 14.63 per cent. The chemical composition of a sample of No. 1 is given below as analysis No. 83:

TABLE 46.

ANALYSIS OF RESIDUAL CLAY, VAIDEN.

	No. 83
Moisture (H_2O)	10.06
Volatile matter (CO_2 etc.)	7.00
Silicon dioxide (SiO_2)	59.22
Iron oxide (Fe_2O_3)	4.70
Aluminum oxide (Al_2O_3)	10.30
Calcium oxide (CaO)	1.68
Magnesium oxide (MgO)	1.18
Sulphur trioxide (SO_3)	.23
Total	94.37

RATIONAL ANALYSIS.

Clay substance	26.06
Free silica	15.76
Impurities	7.89

The red residual clay, No. 2, of the section given above, has the following composition:

TABLE 47.

ANALYSIS OF RESIDUAL CLAY, VAIDEN.

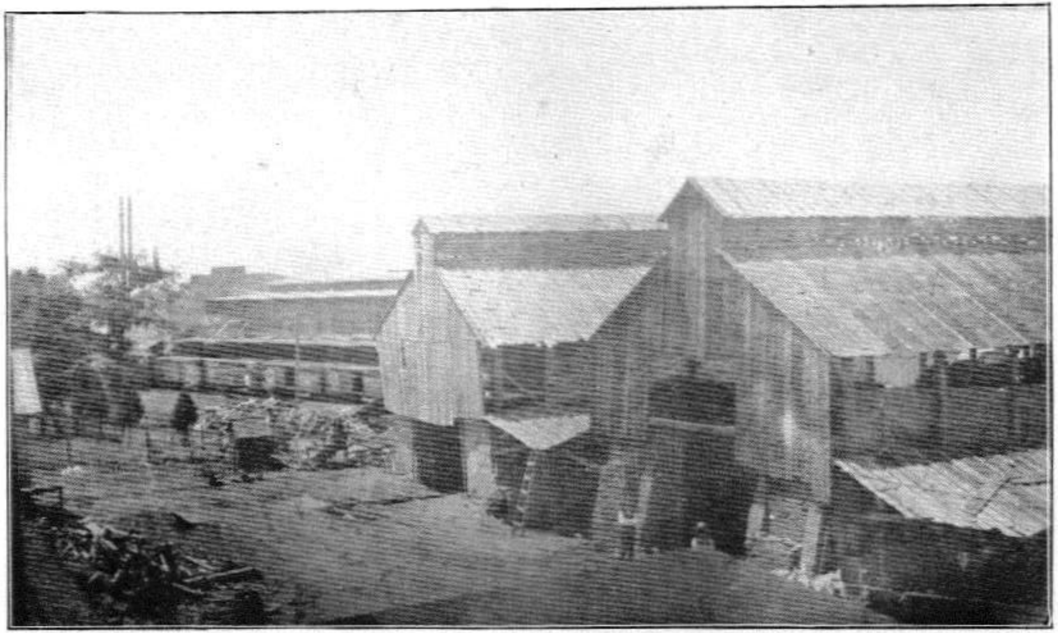
	No. 84
Moisture (H_2O)	6.77
Volatile matter (CO_2 etc.)	6.75
Silicon dioxide (SiO_2)	66.06
Iron oxide (Fe_2O_3)	6.25
Aluminum oxide (Al_2O_3)	9.47
Calcium oxide (CaO)	1.95
Magnesium oxide (MgO)	.72
Sulphur trioxide (SO_3)	.10
Total	97.87

RATIONAL ANALYSIS.

Clay substance	23.96
Free silica	51.58
Impurities	9.02

This clay has too high a shrinkage to be utilized without the aid of non-plastic material. It would also require thorough crushing before it could be used, as it slakes slowly. The non-plastic material of the Lafayette or Columbia near at hand could be used to dilute it.

PLATE XXVII.



UP-DRAFT CLAMP KILNS, END VIEW, WEST POINT.

CLAY COUNTY.

GEOLOGY.

The bed-rock of Clay County belongs to the Cretaceous and the Eocene periods. The eastern part of the county is underlain by the Eutaw (Tombigbee) formation; the central portion by the Selma chalk, and the western part by the Porter's Creek (Flatwoods). The mantle rock formations are the Lafayette and the Columbia. The Lafayette occurs only in isolated areas. The Columbia has a much larger distribution, but there are areas in which the soil rests directly upon the surface of the Selma without intervening mantle rock. Much of the surface clay has been formed by the decomposition of the Selma chalk.

CLAY INDUSTRY.

West Point.—In the pit belonging to the West Point Manufacturing Company, at West Point, the clay rests upon a stratum of the Selma chalk. On weathered surfaces the chalk is white, but unweathered surfaces are blue. The chalk at this point is very fossiliferous, containing many specimens of the genus Inoceramus.

The limestone immediately underlying the clay contains sufficient clay to render it plastic. When molded into brickettes it is white or blue, depending on whether the weathered or unweathered chalk is taken. The burned clay has a white or light yellow color. The brickettes have a tensile strength of 152 pounds per square inch in the unburned state. Its air shrinkage is about 6 per cent. Samples of this limestone and the overlying clay have the following composition:

TABLE 48.

ANALYSES OF SELMA LIMESTONE AND RESIDUAL CLAY, WEST POINT.

	No. 32	*No.* 33
Moisture (H_2O)	4.25	2.75
Volatile matter (CO_2 etc.)	7.77	22.61
Silicon dioxide (SiO_2)	73.70	32.81
Iron oxide (Fe_2O_3)	11.14	4.65
Aluminum oxide (Al_2O_3)	3.81	11.15
Calcium oxide (CaO)	1.04	22.69
Magnesium oxide (MgO)	.00	1.53
Sulphur trioxide (SO_3)	.21	1.55
Total	99.97	99.74

No. 32. Residual clay.
No. 33. Selma limestone.

The above mentioned limestone contains 28.20 per cent of clay and a small per cent of free silica. Doubtless the low percentage of calcium carbonate is due to the solvent action of circulating waters which dissolved out and carried away much of this soluble constituent and produced a concentration of such insolubles as clay and silica. As the distance from the limestone to the top of the clay deposit increases, there is a corresponding decrease in the amount of calcium carbonate. On the other hand, the amount of silica increases to the top while the amount of alumina increases to a certain point, and then decreases as the amount of free silica increases.

The clay immediately overlying the limestone contains a high per cent of calcium carbonate in some places. In burning, the calcium compound is calcined and when the bricks absorb moisture the lime slakes and produces heat. The heat and the swelling of the lime cause the brick to crack open. This would not occur if the lime was thoroughly mixed throughout the clay in small particles. The clay contains soluble salts, which produce efflorescence on the brick in drying. The principal salt is calcium sulphate, formed by the decomposition of pyrite in the presence of calcium carbonate. This salt is brought to the surface by the water which comes from the brick during drying, and forms a white coating on the surface. The bottom clay is so plastic that it gives trouble in drying when used alone. The best results are to be obtained by not taking the clay too close to the limestone; and by mixing the lower clay with the clay from the more non-plastic layer. Other non-plastic materials, such as sand and cinders, may be used to facilitate the drying of the clay; but by the use of the top clay the loss of bonding power is not so greatly diminished. This clay was used several years ago by Mr. John Mahafa in the manufacture of drain tile. It is stated that the lack of demand for tile at that time caused the enterprise to be abandoned.

On comparing the analysis of No. 32 with that of No. 33 an increase in silica from the limestone to the clay of nearly double may be noted. The lime element, however, has decreased 18.94 per cent.

Clay No. 32 has a total shrinkage of 10 per cent. It loses 42 per cent in weight in drying and burning. The burned brickettes are pale yellow due to the presence of lime which destroys the coloring effects of the iron. The average tensile strength of 12 unburned brickettes was 152 pounds per square inch. The minimum strength was 122

Plate XXVIII.

TAKING BRICK FROM OFF-BEARING BELT OF AN END-CUT MACHINE.

pounds and the maximum 172 pounds. It has an absorption of 16.86 per cent. When mixed with 10 per cent of cinders and burned, it has an absorption of 14.28 per cent; when mixed with 10 per cent of coal, it has an absorption of 12.72 per cent.

The clay at the top of the pit has suffered a still greater loss in soluble constituents and shows an increase in insoluble elements. The following analysis shows its composition:

TABLE 49.

ANALYSIS OF SURFACE CLAY, WEST POINT.

	No. 34
Moisture (H_2O)	2.41
Volatile matter (CO_2 etc.)	7.66
Silicon dioxide (SiO_2)	73.70
Iron oxide (Fe_2O_3)	11.14
Aluminum oxide (Al_2O_3)	3.81
Calcium oxide (CaO)	1.04
Magnesium oxide (MgO)	.00
Sulphur trioxide (SO_3)	.21
Total	99.97

RATIONAL ANALYSIS.

Clay substance	9.63
Free silica	69.22
Impurities	12.34

This clay probably contains a mixture of Lafayette sand and Columbia loam, both of which have been washed down from a neighboring elevation. The amount of impurities exceeds the amount of clay. The large per cent of free silica renders the clay non-plastic. However, it supplies non-plastic material which may be used for diluting the more plastic clay below.

The Welch-Trotter Brick Manufacturing Company operates a yard on the line of the Illinois Central Railroad at West Point about ½ mile south of the station. The plant was established in 1905. The clay used is mostly residual clay from the Selma chalk, though the upper portion may be in part Columbia loam. The pit has been opened to a depth of 7 to 8 feet. The lower clay is very plastic. A sample of clay analyzed from near the bottom of the pit gave the following results:

TABLE 50.

ANALYSIS OF CLAY USED AT THE WELCH-TROTTER BRICK PLANT, WEST POINT.

	No. 44
Moisture (H_2O)	3.45
Volatile matter (CO_2 etc.)	5.58
Silicon dioxide (SiO_2)	72.32
Iron oxide (Fe_2O_3)	7.44
Aluminum oxide (Al_2O_3)	8.74
Calcium oxide (CaO)	1.55
Magnesium oxide (MgO)	.47
Sulphur trioxide (SO_3)	.51
Total	100.06

RATIONAL ANALYSIS.

Clay substance	22.11
Free silica	62.05
Impurities	9.97

The clay from the lower layers of the Welch-Trotter pit does not dry readily, and is used only when mixed with the upper leaner clay. The shrinkage of the lower clay is very excessive. The absence of non-plastic material of large grain permits a very slow transfer of water from the center of the brick. Thus the outside becomes dry and shrinks more rapidly than the center, thereby producing cracks.

Two samples of clay from the middle portion of the bed show the following chemical composition:

TABLE 51.

ANALYSES OF CLAYS, WEST POINT.

	No. 45	*No.* 47
Moisture (H_2O)	3.95	3.10
Volatile matter (CO_2)	5.12	3.75
Silicon dioxide (SiO_2)	71.45	76.86
Iron oxide (Fe_2O_3)	5.00	9.50
Aluminum oxide (Al_2O_3)	11.68	3.75
Calcium oxide (CaO)	1.45	1.25
Magnesium oxide (MgO)	.76	.45
Sulphur trioxide (SO_3)	.34	.34
Total	99.75	98.70

RATIONAL ANALYSIS.

Clay substance	28.55
Free silica	57.73
Impurities	7.55

Clay No. 45 requires 17 per cent of water to render it plastic. It shrinks about 6⅔ per cent. It burns without cracking to a red color. The tensile strength of the raw brickettes is 92 pounds per square inch. The burned brickettes have a strength of 130 pounds per square inch.

This clay has about the proper amount of clay substances and the proper physical properties to make a good clay for the manufacture of a stiff-mud brick. The thickness of the layer is not sufficient to warrant its exclusive use. Therefore a mixture of top, bottom and middle clay is used.

Clay No. 47 is noticeable for its high silica content and the small amount of alumina. It has a peculiar texture and is somewhat light and spongy. Its total shrinkage is 5 per cent. It requires the addition of 19 per cent of water for molding. The raw clay has a tensile strength of 140 pounds per square inch. The burned brickettes have strength of 138 pounds per square inch. A medium burned brickette absorbs 10.52 per cent of water. The tensile strength is high when the small amount of clay substance is considered. The amount of impurities in the clay is in excess of the clay substance.

The clay from the top of the pit contains more silica and less alumina than the clay from the middle and lower portions of the pit. An analysis of a sample of the top clay is given below:

TABLE 52.

ANALYSIS OF SURFACE CLAY, WEST POINT.

	No. 40
Moisture (H_2O)	3.50
Volatile matter (CO_2)	2.52
Silicon dioxide (SiO_2)	75.95
Iron oxide (Fe_2O_3)	5.08
Aluminum oxide (Al_2O_3)	9.62
Calcium oxide (CaO)	1.25
Magnesium oxide (MgO)	.74
Sulphur trioxide (SO_3)	.34
Total	99.00

RATIONAL ANALYSIS.

Clay substance	24.33
Free silica	64.74
Impurities	7.41

The above mentioned clay may be molded by the addition of 18 per cent of water. The burned brickettes are red in color and free from cracks and checks. The raw clay has a tensile strength of 283 pounds. The total shrinkage is about 6 per cent. The increase in tensile strength over the clay from the middle portion of the pit is noticeable. The increase is doubtless due to the greater amount of clay substance.

CHICKASAW COUNTY.

GEOLOGY.

The eastern portion of Chickasaw County is underlain by the Ripley and Selma divisions of the Cretaceous. The western portion is underlain by the Porter's Creek and the Wilcox. The Lafayette, the residual Selma and the Columbia overlie the bed-rock formations. The clays used in the manufacture of brick are from these surface formations.

CLAY INDUSTRY.

Okolona.—At Okolona deposits of yellow clay, for the most part residual Selma, rest upon that formation. This clay is used by Hawkins and Hodges in the manufacture of brick. This brick plant was established in Okolona in 1895. The brick are molded in a stiff-mud machine of the auger-type. They are cut with an end-cut machine. The kilns in use are rectangular up-draft kilns of the clamp type. The clay in the pit is of two kinds: the upper is sandy, the lower is plastic and contains blue and red streaks. The limestone underlying the clay at this point has the following composition:

TABLE 53.

ANALYSIS OF SELMA LIMESTONE, OKOLONA.

	No. 19
Moisture (H_2O)	1.10
Volatile matter (CO_2 etc.)	34.20
Silicon dioxide (SiO_2)	8.70
Iron oxide (Fe_2O_3)	6.00
Aluminum oxide (Al_2O_3)	.00
Calcium oxide (CaO)	45.62
Magnesium oxide (MgO)	1.72
Sulphur trioxide (SO_3)	1.11
Total	98.45

Another sample of the limestone has the chemical properties indicated below:

TABLE 54.

ANALYSIS OF SELMA CHALK, OKOLONA.

	No. 12a
Moisture (H_2O)	6.35
Volatile matter (CO_2 etc.),	31.11
Silicon dioxide (SiO_2)	8.80
Iron oxide (Fe_2O_3)	4.08
Aluminum oxide (Al_2O_3)	2.86
Calcium oxide (CaO)	45.51
Magnesium oxide (MgO)	0.36
Sulphur trioxide (SO_3)	0.38
Total	99.45

The bottom clay is very plastic and is derived from the Selma by the solvent action of surface waters. The decomposition of pyrite contained in the chalk forms iron concretions called "buckshot," in the lower part of the clay bed. They are not uniformly distributed but are found in streaks in the lower layers and should be avoided, as they interfere with cutting and cause flaws in the brick unless crushed.

Houston.—The Pope Brick Manufacturing Company established a plant at Houston in 1903. The clay used is red clay, belonging probably to the Lafayette. The brick are molded in a stiff-mud machine of the plunger type. The brick are dried by heating under covered sheds. The burning is done in rectangular up-draft kilns. The clay is plastic, especially in the bottom layers, and care must be exercised in order not to dry too rapidly. The use of the non-plastic surface loam serves to increase the speed of drying.

New Houlka.—The New Houlka Brick Manufacturing Company's plant was established at New Houlka in 1904. The clay is prepared in a disintegrator and tempered in a pug mill. It is molded in an auger-type stiff-mud machine. The brick are cut with an end-cut machine and burned in rectangular up-draft kilns. The stratigraphy of the clay pit is as follows:

Section of Clay Pit, New Houlka.

	Feet
4. Yellow loam	2–3
3. Gray clay, very plastic	4–5
2. Grayish clay with iron concretions (buckshot)	1
1. Limestone with shells (Clayton)	...

Clays Nos. 2 and 3 have very similar properties to the Porter's Creek or Flatwoods clays. Since New Houlka lies within the edge of that area, these clays are probably residual clays from that group. Layer No. 4 may consist partly of this residual clay and partly of foreign material.

A sample of clay from No. 3 has the composition recorded below:

TABLE 55.

ANALYSIS OF BRICK CLAY; NEW HOULKA.

	No. 96	*No.* 95
Moisture (H_2O)	3.86	4.00
Volatile matter (CO_2 etc.)	3.60	6.30
Silicon dioxide (SiO_2)	75.85	71.75
Iron oxide (Fe_2O_3)	5.45	5.95
Aluminum oxide (Al_2O_3)	4.95	5.85
Calcium oxide (CaO)	1.87	2.05
Magnesium oxide (MgO)	.49	.14
Sulphur trioxide (SO_3)	.04	.48
Total	96.11	96.52

RATIONAL ANALYSIS.

	No. 96	*No.* 95
Clay substance	12.52	14.79
Free silica	68.28	62.81
Impurities	7.86	8.62

No. 95 from No. 4
No. 96 from No. 3

The absorption of clay No. 96 is 12.96 per cent; tensile strength, raw, 75 pounds. The absorption of a mixture of Nos. 95 and 96 is 16 per cent; tensile strength, raw, 60 pounds; burned, 75 pounds; shrinkage, 5 per cent.

CHOCTAW COUNTY.

GEOLOGY.

Choctaw County lies within the area of the Wilcox Eocene, with a small outcrop of Claiborne in the southwestern corner. The mantle rock belongs to the Lafayette and the Columbia.

The surface clays have been used at Ackerman in the manufacture of brick. The plant is not now in operation. The brick were made by the soft-mud process and burned in scove kilns. There seems to be a suitable body of clay for the manufacture of brick just west of the Mobile, Jackson and Kansas City station. The clay is bluish in color and has a thickness of about 15 feet.

An exposure of the Wilcox and later formations may be seen in a cut on the Illinois Central Railroad one-half mile east of Ackerman. At the bottom of the cut there are 10 feet of pink colored sand. Overlying the pink sand there are 10 feet of orange sand with little partings of clay. Near the top there is a thin layer of ironstone which has been broken up, the pieces being turned at various angles. On the slopes there is a bed of yellow loam which decreases in thickness toward the top until at the apex there is not more than 1 foot of it. The best clays for brick making in this country are to be found in the second bottom deposits. Some of the upland loams may be used in the soft-mud process.

COAHOMA COUNTY.

GEOLOGY.

The surface of Coahoma County is occupied by the recent alluvium deposited by the Mississippi River upon its flood plain. The rocks of the Wilcox formation underlie this alluvial deposit at a depth of from 25 to 50 feet.

At a number of places in Coahoma County the dark "buckshot" clay of the alluvium has been burned successfully for road ballast. There are several short sections of roads upon which the ballast has been used with satisfactory results. The burned clay ballast is said to be much more economical than gravel. The cost per mile for the burned clay ballast is about $1,500.

CLAY INDUSTRY.

Clarksdale.—An experiment in road building carried on at Clarksdale by the U. S. Bureau of Public Roads gave very satisfactory results. The experiment was made upon a piece of road having a length of 300 feet. The road was first plowed as deep as it was possible for a four-horse team to pull the plow. It was then cross-furrowed and pieces of wood were placed across the furrows resting upon the crests of the intervening ridges. The wood was then covered with clay and more wood placed upon the surface of the clay. This wood was covered with more clay. Fires were then kindled in the furrows beneath the wood. The burning of the wood reduced the overlying clay to a "clinker." After the clay had been burned it was rolled down and compacted forming a close, hard, non-plastic surface. The several items of cost were as follows:

TABLE 56.

COST OF BUILDING 300 FEET OF ROAD WITH BURNED CLAY BALLAST, CLARKSDALE.

30½ cords of wood at $1.30 per cord	$39.65
20 loads of bark and chips at $0.30	6.00
Labor at $1.25 per day and teams at $3.00 per day	38.30
Total cost of 300 feet	$83.95

Total cost per mile at this rate, $1,478.40.

The clay ballast has not the wearing qualities of the hard chert gravel, such as the Tishomingo gravel, but with proper care it can be made very serviceable, and in a land of such paucity of good road metal and great abundance of timber this method of road making has its advantages. It is to be hoped that further experiments will be tried in the Delta and in other parts of the State. By the use of its convict labor the State could conduct experiments of this kind upon the roads on and near Sunflower farm, using the timber cut from the land in the process of clearing

The alluvial clays of Coahoma County are used at Clarksdale for the manufacture of both brick and drain tile. The Clarksdale Brick and Tile Mfg. Company has opened a pit in which the following stratigraphical conditions exist:

Section of Clay Pit, Clarksdale.

	Feet
5. Soil and sandy loam	7
4. Dark colored clay (buckshot)	8
3. Sandy loam	12
2. Sands	3
1. Gravel bowlders in bottom	...

Samples of clay taken from beds Nos. 5 and 4 gave the results shown in analyses Nos. 62 and 61 respectively.

TABLE 57.

ANALYSES OF CLAYS USED BY THE CLARKSDALE BRICK AND TILE CO., CLARKSDALE.

	No. 62	*No.* 61
Moisture (H_2O)	2.81	6.78
Volatile matter (CO_2 etc.)	4.23	7.97
Silicon dioxide (SiO_2)	74.45	58.52
Iron oxide (Fe_2O_3)	3.38	6.87
Aluminum oxide (Al_2O_3)	11.62	16.20
Calcium oxide (CaO)	1.69	1.75
Magnesium oxide (MgO)	.94	.36
Sulphur trioxide (SO_3)	.43	.51
Total	99.55	98.96

RATIONAL ANALYSES.

	No. 5	No. 4
Clay substance	29.39	40.98
Free silica	60.89	39.47
Impurities	8.44	9.49

The clay from No. 5 has a total shrinkage of 6⅔ per cent; tensile strength raw, 115 pounds; burned, 155 pounds; requires 19 per cent of water. Clay from No. 4 has total shrinkage of 5 per cent; requires 18 per cent of water; tensile strength raw, 132 pounds; burned, 258 pounds.

The clay is prepared by the use of a granulator and disintegrator and after being tempered in a pug mill is molded in an auger, stiff-mud machine. The clay from layer No. 4 contains more clay than sand. Its shrinkage is excessive and it can not be used alone in the manufacture of brick or tile; when mixed with the non-plastic material from the other layers of the pit it produces a good grade of ware. Careful selection of clay and mixing is necessary to obtain the best results. Whenever a large proportion of the plastic clay is used difficulties of rapid drying of the wares are greatly increased. The burned brickettes have an absorption of 12.96 per cent.

The Rheinhart firm of Clarksdale also operates a plant for the manufacture of brick and drain tile. In the clay pit which they have opened in the alluvial deposit the following layers are encountered:

Section of Rheinhart Clay Pit, Clarksdale.

	Feet
4. Soil and sandy loam (top)	3
3. Sandy clay	8
2. Dark clay (buckshot)	5
1. Sand in bottom	...

The analysis of clay from layer No. 2 is here given:

TABLE 58.

ANALYSIS OF BUCKSHOT CLAY USED AT THE RHEINHART BRICK AND TILE FACTORY, CLARKSDALE.

	No. 63
Moisture (H_2O)	6.70
Volatile matter (CO_2 etc.)	8.31
Silicon dioxide (SiO_2)	59.47
Iron oxide (Fe_2O_3)	7.25
Aluminum oxide (Al_2O_3)	14.00
Calcium oxide (CaO)	1.50
Magnesium oxide (MgO)	.83
Sulphur trioxide (SO_3)	.43
Total	98.49

RATIONAL ANALYSIS.

Clay substance	35.42
Free silica	40.03
Impurities	10.01

The gray "buckshot" clay is mixed with a more sandy clay for the manufacture of brick and drain tile. The amount of clay substance permits the addition of considerable non-plastic material without destroying the bonding power.

In the manufacture of the smaller size of tile a horizontal machine is used, but for the larger sizes a vertical attachment is employed. The brick and tile are burned in kilns of the beehive type.

DE SOTO COUNTY.

GEOLOGY.

The extreme western part of De Soto County lies within the alluvial plain of the Yazoo basin. The remainder of the country lies at a higher level and has a much more rugged topography. The hilly portion is covered with surfacial deposits of Lafayette, Loess and Columbia. The sub-formation of the county is the upper portion of Hilgard's Lignitic (Wilcox).

CLAY INDUSTRY.

Lake View.—At Lake View, a station on the Yazoo and Mississippi Valley Railroad, one-half mile south of the Tennessee line, the flood plain meets the bluffs. At a point where the railroad makes a cut through the bluffs the following section is revealed:

Section of Loess and Lafayette One-Half Mile South of Lake View.

	Feet
4. Soil	1
3. Brownish sandy loam (Loess)	10
2. Gravel and sand (Lafayette)	5
1. Gravel and conglomerate (Lafayette)	10

The gravels of Nos. 1 and 2 are largely white, yellow and blue flints. In some places they are cemented together, forming masses of pudding stone, or conglomerate of considerable size. The cementing substance is limonite. No. 1 is Lafayette and No. 2 is probably Lafayette, though the latter may be Natchez. No. 3 is Loess and its derivative, though no concretions or gastropod shells were found in it.

A sample of clay from No. 2 was collected for analysis and gave results as follows:

TABLE 59.

ANALYSIS OF CLAY, LAKE VIEW.

	No. 50
Moisture (H_2O)	1.31
Volatile matter (CO_2 etc.)	5.28
Silicon dioxide (SiO_2)	75.33
Iron oxide (Fe_2O_3)	5.60
Aluminum oxide (Al_2O_3)	7.80
Calcium oxide (CaO)	1.25
Magnesium oxide (MgO)	1.19
Sulphur trioxide (SO_3)	.60
Total	98.36

RATIONAL ANALYSIS.

Clay substance	19.73
Free silica	66.16
Impurities	9.64

The physical character of No. 2 is as follows: The total shrinkage is 3⅓ per cent; water required for plasticity, 17 per cent; tensile strength raw, 65 pounds per square inch; burned, 83 pounds; absorption, 13.33 per cent; color, cherry red. The clay lacks the plasticity essential to stiff-mud brick, but it may be used for soft-mud brick, or, by mixing with the more plastic "buckshot" clays of the bottom, it may be used by the stiff-mud methods.

About one mile south of Lake View is located the works of the Valley Brick and Tile Company. The products of their plant are brick, hollow blocks and drain tile. The brick and blocks are molded in a stiff-mud machine of the horizontal auger type. The brick are cut by an automatic side-cut machine. Two types of kilns are used, namely, an up-draft kiln of the rectangular, clamp type and a down-draft beehive kiln.

The clay used is obtained from alluvial deposits of the Yazoo basin. It burns to a red color but explodes and flies to pieces if the heat be applied too rapidly. In air-drying it shrinks 15 per cent, but its total shrinkage after burning is only 10 per cent, so that the air shrinkage is partly compensated by swelling in burning. The water required to render it plastic is 22 per cent. In the raw state the air-dried brickettes have a tensile strength of 183 pounds. When burned they exhibit a strength of 193 pounds. The chemical composition of a sample of the clay is as follows:

TABLE 60.

ANALYSIS OF ALLUVIAL CLAY, LAKE VIEW.

	No. 51
Moisture (H_2O)	5.15
Volatile matter (CO_2 etc.)	11.70
Silicon dioxide (SiO_2)	58.92
Iron oxide (Fe_2O_3)	7.45
Aluminum oxide (Al_2O_3)	11.75
Calcium oxide (CaO)	1.10
Magnesium oxide (MgO)	1.01
Sulphur trioxide (SO_3)	.48
Total	97.56

RATIONAL ANALYSIS.

Clay substance	29.72
Free silica	45.11
Impurities	10.04

Hernando.—At Hernando the surface formations are Lafayette and Columbia. The latter seems to be a modified, or at least a partly residual, form of the Loess. An outcrop in a ravine south of the station reveals the following stratigraphy:

Section of Ravine Near Hernando.

	Feet
5. Soil	1
4. Brown loam, light in color	6
3. Brown loam, dark in color	6
2. Gravel and red sand	10
1. Reddish clay	...

The rocks of Nos. 1 and 2 belong to the Lafayette, while those of 3 and 4 are Columbia. A sample of clay from No. 4 has the following physical properties: It requires 10 per cent of water to render it plastic. The tensile strength of the raw clay is 90 pounds; when soft burned its strength is only 85 pounds. It burns to a red color. The total shrinkage is only about 1 per cent. The loss of weight in drying and burning is 18 per cent. The burned brickettes have an absorption of 10.76 per cent.

GRENADA COUNTY.

GEOLOGY.

The subformation of the eastern part of Grenada County is the Wilcox (Lagrange). The Silicious Claiborne, or Tallahatta buhrstone, underlies the western part of the county. The mantle formations are the Lafayette, the Loess and the Columbia loam.

CLAY INDUSTRY.

Grenada.—At Grenada the Columbia loam clay is used in the manufacture of brick. The Carl Brick Company operates a plant south of the Illinois Central Railroad station. Brick are manufactured by the soft-mud process and are burned in rectangular, up-draft kilns of the scove type. About 8 feet of clay is exposed in the pit. The lower portion is much more plastic than the upper portion. Two samples of the clay have the following chemical properties:

TABLE 61.

ANALYSES OF COLUMBIA CLAY, GRENADA.

	No. 79	
Moisture (H_2O)	1.91	2.31
Volatile matter (CO_2 etc.)	3.34	2.83
Silicon dioxide (SiO_2)	73.44	73.11
Iron oxide (Fe_2O_3)	5.97	5.62
Aluminum oxide (Al_2O_3)	10.35	10.44
Calcium oxide (CaO)	1.87	1.15
Magnesium oxide (MgO)	1.12	.98
Sulphur trioxide (SO_3)	.13	.18
Total	98.14	96.62

RATIONAL ANALYSIS.

Clay substance	26.18	26.41
Free silica	61.27	60.84
Impurities	9.09	8.93

The more sandy upper portion of the clay is mixed with the lower plastic portion in the manufacture of brick. The sandy clay has a total shrinkage of 5 per cent. It requires the addition of 17 per cent of water to render it plastic. The tensile strength of the raw clay is 55 pounds per square inch. When burned it has a strength of 94 pounds per square inch. The burned brickettes have an absorption of 15.57 per cent. The lower clay requires 17.9 per cent of water to render it plastic. The total shrinkage is 7 per cent. The tensile strength in the raw state is 66 pounds per square inch. The burned brickettes have a strength of 127 pounds per square inch.

A shale-like clay outcrops along the banks of the Yalobusha River at Grenada. At the Bledsoe Brick Company's plant this clay has a thickness of 40 feet, as shown by the record of an artesian well drilled by Mr. Bledsoe.

TABLE 62.

RECORD OF ARTESIAN WELL AT THE BLEDSOE BRICK YARD, GRENADA.

	Thickness	*Depth*
Yellow loam and gray clay	9 feet	9 feet
White sand, water bearing	12 "	21 "
Dark clay shale	40 "	61 "
Sand and shale (water at 200 feet)	160 "	200 "
Greenish sand and clay	25 "	225 "
Sand and clay (artesian water at 465 feet)	240 "	465 "
Sand, and at 475 feet a hard flint rock	10 "	475 "
Sand and water	25 "	500 "

The clay is dark in color and of low specific gravity. The following analysis shows the chemical composition:

TABLE 63.

ANALYSIS OF SHALE-CLAY, GRENADA.

	No. 56a
Moisture (H_2O)	5.91
Loss on ignition (CO_2 etc.)	8.75
Silica (SiO_2)	61.80
Ferric oxide (Fe_2O_3)	3.88
Alumina (Al_2O_3)	16.50
Lime (CaO)	1.00
Magnesia (MgO)	.25
Sulphur trioxide (SO_3)	.19
Total	98.28

RATIONAL ANALYSIS.

Clay substance	41.74
Free silica	42.40
Impurities	5.82

Mr. O. F. Bledsoe thinks this clay is suitable for the manufacture of drain tile, but he has not yet given it a trial. The Bledsoe Brick and Tile Company was established in 1901. They have the requisite machinery for the manufacture of brick by the soft-mud, the stiff-mud or the dry-press process. The clay so far used is a surface clay, having a thickness of about 9 feet. The pit exhibits the following section:

Section of Clay Pit at Grenada.

	Feet
4. Brown sandy loam	2
3. Whitish clay	4
2. Dark colored joint clay	3
1. White sand	12

The pit is located on the second bottom of the Yalobusha River.

Holcomb.—At Holcomb, Fred Gulo established a brick plant in 1906. The brick are molded in a soft-mud machine operated by horse power. They are dried in the sun in an open yard. Some of the brick are repressed before being burned in up-draft, scove kilns. The clay used is a surface clay which is tempered by the use of sand. It is probably Columbia in age. The burned brick are red in color.

HINDS COUNTY.

GEOLOGY.

The formations occupying the subsurface of Hinds County are Jackson, Vicksburg, and Grand Gulf. All of these formations belong to the Tertiary period. The Lafayette and the brown loam phase of the Columbia and the alluvium of the Pearl River valley form the unconsolidated sediments of the mantle rock. The Columbia loam forms the surface of the greater part of the country, the Lafayette occupying the higher isolated areas.

CLAY INDUSTRY.

Jackson.—At Jackson the clay at the base of the brown loam is being used in the manufacture of brick. The W. B. Taylor plant was established in 1881, and has been in continuous operation since that time. The clay pit has the following layers:

Section of the Taylor Clay Pit, Jackson.

	Feet
3. Soil	1
2. Clay, brown, jointed in lower part	6–8
1. Yellowish clay with gravel in upper part	4

The chemical composition of a sample of clay from No. 2 is given below:

TABLE 64.

ANALYSIS OF BRICK CLAY, JACKSON.

	No. 73
Moisture (H_2O)	1.80
Volatile matter (CO_2 etc.)	4.37
Silicon dioxide (SiO_2)	75.21
Iron oxide (Fe_2O_3)	5.47
Aluminum oxide (Al_2O_3)	10.71
Calcium oxide (CaO)	.87
Magnesium oxide (MgO)	.93
Sulphur trioxide (SO_3)	.52
Total	99.88

RATIONAL ANALYSIS.

Clay substance	27.09
Free silica	62.62
Impurities	7.79

The above mentioned clay is used in the manufacture of brick. The whole section of the clay is taken and mixed. The lower portion of the clay has a joint structure, the faces of the blocks being covered with a white efflorescence. This may be a deposit of gypsum brought up from the underlying clay by circulating waters. The brown clay has an air shrinkage of 3½ per cent. The tensile strength of the raw clay is 50 pounds per square inch. The clay requires an addition of 17 per cent of water for plasticity.

The clay in No. 1 of the Taylor clay pit has the following chemical composition:

TABLE 65.

ANALYSIS OF BRICK CLAY, JACKSON.

	No. 72
Moisture (H_2O)	4.25
Volatile matter (CO_2 etc.)	8.01
Silicon dioxide (SiO_2)	67.72
Iron oxide (Fe_2O_3)	5.51
Aluminum oxide (Al_2O_3)	10.86
Calcium oxide (CaO)	.85
Magnesium oxide (MgO)	.70
Sulphur trioxide (SO_3)	.54
Total	98.44

RATIONAL ANALYSIS.

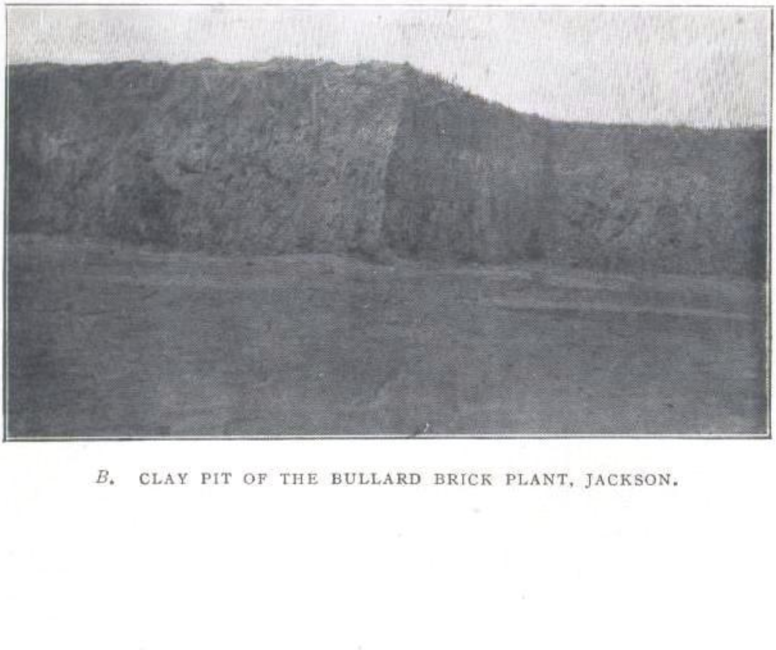
Clay substance	27.47
Free silica	12.77
Impurities	7.60

The gravel lying on this clay is probably Lafayette. The clay which rests upon the Jackson is probably residual clay from that formation. It has a total shrinkage of 8 per cent. It requires 17 per cent of water for plasticity. Its tensile strength raw is 75 pounds per square inch; burned, it has a strength of 87 pounds. The absorption of the burned brickettes is 11.11 per cent.

The Bullard Brick Mfg. Company also operates a plant at Jackson. They use the brown loam clay, which has a thickness varying from 6 to 9 feet (see Plate XXXV B). The clay contains gravel at the base and rests upon a stiff plastic clay which belongs to the Jackson formation. This company used a soft-mud machine for about three years, but abandoned its use because of excessive shrinkage in the clay. The plant was established in 1899. The brick are molded in a stiff-mud machine of the auger type. The brick are cut by the use of

PLATE XXIX.

A. POWER HOUSE OF THE BULLARD BRICK PLANT, JACKSON.



B. CLAY PIT OF THE BULLARD BRICK PLANT, JACKSON.

an automatic end-cut machine. The brick are dried in covered sheds; some are stacked and others placed on pallets. They are burned in up-draft kilns of the clamp type.

The brown loam, which is doubtless a modified form of the Loess, is probably not thicker than 20 feet anywhere in the county. It is the best brick clay in the county, but is not of the same quality in all parts of the county. In some deposits it lacks sufficient bonding power. In nearly all places it presents two phases, a loam phase in the upper part and a clay phase in the lower part of the deposit. The clay phase may be but poorly represented, in which case the deposit will not be suited to the manufacture of brick.

HOLMES COUNTY.

GEOLOGY.

Holmes County lies within the area which is underlain by the Claiborne group. The Tallahatta buhrstone forms the bed-rock of the northern part of the county, and the "Claiborne Calcareous" the southern part. The principal mantle rock formations belong to the Lafayette, the Loess, the Columbia and the Alluvium of the Yazoo delta.

CLAY INDUSTRY.

Lexington.—In the northern part of the town of Lexington, the stratigraphy of some of the surficial formations is revealed in numerous gullies or gulches. The soft, unconsolidated character of the sediments has developed a "bad land" type of topography. The general stratigraphic conditions are given below:

Section of the Lafayette, Lexington.

	Feet
6. Soil	1
5. Brownish colored loam and clay	6–10
4. Orange sand with white sandy clay gravel	10–15
3. White and purple sand and clay with small gravel	6–10
2. Larger gravel with some sand	3–5
1. Cross-bedded reddish sand	3–6

Layer No. 5 is doubtless Columbia loam. The remaining layers below belong to the Lafayette. These layers vary in thickness and composition from outcrop to outcrop. The gravels are for the most part brown cherts, though there are some white and blue cherts, and some transparent quartz pebbles. Some of the cherts are fossiliferous. The shapes of some are irregular, but the majority are smooth and well rounded pebbles. The size of the pebbles vary from the size of a pea to a little larger than the size of a man's fist. The larger sizes are not numerous. The irregularity in the bedding of the gravel may be seen from figure 14.

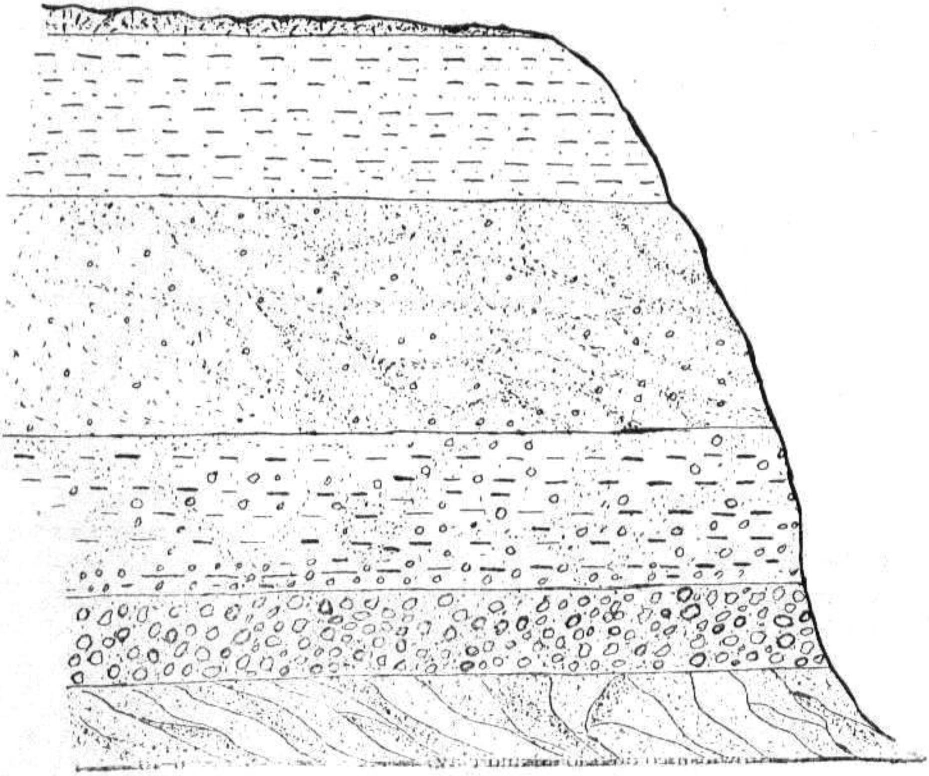


FIGURE 13. SECTION OF THE LAFAYETTE, LEXINGTON.

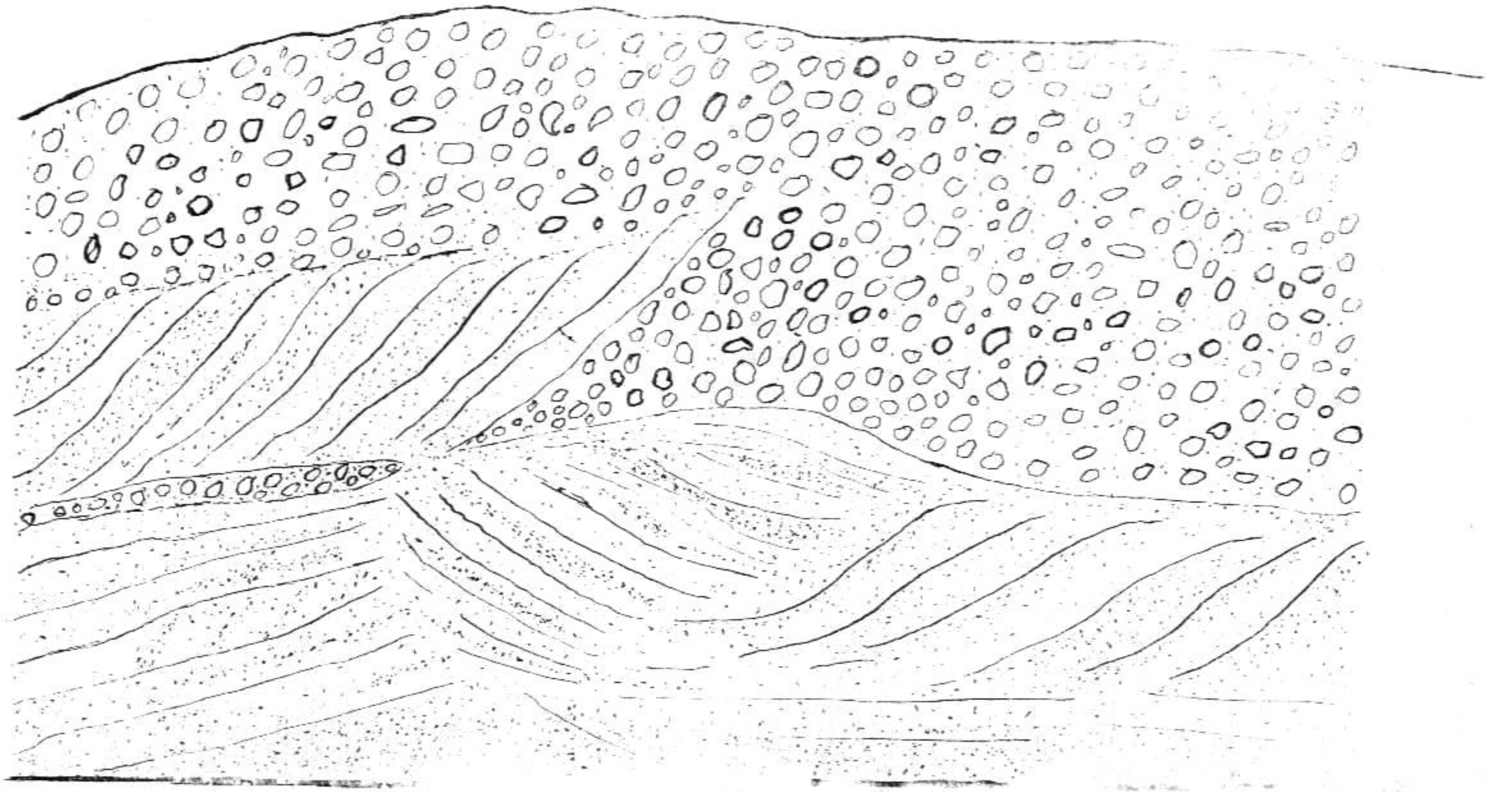


FIGURE 14. CROSS BEDDING IN THE LAFAYETTE, LEXINGTON.

A sample of clay from layer No. 5 has the following composition:

TABLE 66.

ANALYSIS OF COLUMBIA CLAY, LEXINGTON.

	No. 59
Moisture (H_2O)	1.56
Volatile matter (CO_2 etc.)	4.14
Silicon dioxide (SiO_2)	75.65
Iron oxide (Fe_2O_3)	6.20
Aluminum oxide (Al_2O_3)	8.70
Calcium oxide (CaO)	1.50
Magnesium oxide (MgO)	1.60
Sulphur trioxide (SO_3)	.26
Total	99.31

RATIONAL ANALYSIS.

Clay substance	22.01
Free silica	65.42
Impurities	9.26

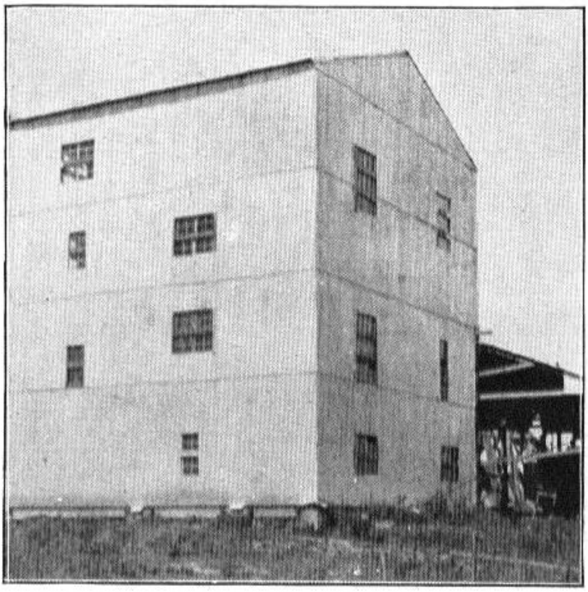
Clay No. 59 shrinks about 3 per cent in drying and burning. It requires the addition of 16 per cent of water to render it plastic. The tensile strength of the raw clay is 58 pounds per square inch. When burned it has a strength of 95 pounds per square inch. When allowed to dry in the open air it cracks badly. It lacks bonding power and could be used only by mixing with a more plastic clay.

Durant.—The Love Wagon Manufacturing Company has operated a brick plant at Durant since 1893. The first clay pit and yard was located east of the line of the Illinois Central Railroad. New machinery was installed in this yard in 1897. In 1905 this yard was abandoned and a new one opened in the western part of the town on a spur of the railroad.

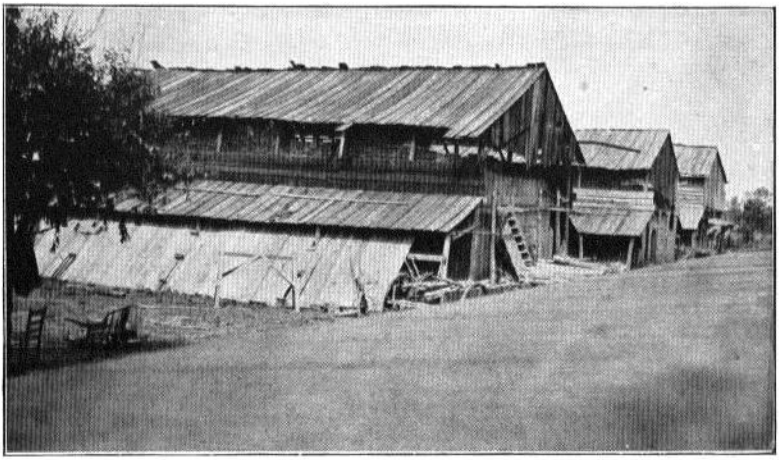
The yard has been greatly enlarged and new machinery installed.

The clay pit has been opened to a depth of 8 or 10 feet. The clay is brownish yellow in color, but contains streaks of gray clay which contain ironstone concretions of small size. Water is supplied to the plant from an artesian well. The record of this well shows a thickness of 40 feet for the surface formation. At a depth of 7 to 8 feet a hard stratum was encountered. Underlying the clay is a bed of sand. In the old pit the sand bed has a thickness of about 15 feet. Ironstone pebbles are very abundant in the lower part of the bed.

The clay is prepared in a granulator and disintegrator. It is



A. POWER HOUSE OF THE LOVE BRICK PLANT, DURANT.



B. UP-DRAFT CLAMP KILNS, DURANT.

tempered in a pug mill and molded in a stiff-mud machine. The brick are burned in rectangular up-draft kilns. A waste heat dryer is being installed.

KEMPER COUNTY.

GEOLOGY.

The northeastern part of Kemper County has for its subformations Cretaceous strata belonging to the Selma and Ripley epochs. The remainder of the county is occupied by Eocene rock. The mantle formations are Lafayette, Columbia and the residual deposits of the bed-rock.

CLAY INDUSTRY.

Wahalak.—At Wahalak the sticky Flatwoods clay rests upon a hard rock, probably sandstone. On Wahalak Creek, 1 mile south of Wahalak, there is exposed the following section:

Section on Wahalak Creek, One Mile South of Wahalak.

	Feet
3. Yellowish-red clay	6
2. Shally, friable sandstone	3
1. Blue limestone	3

A sample of clay from the well of D. V. Porter in Wahalak has an air shrinkage of 10 per cent and a tensile strength, raw, of 112 pounds per square inch. When burned its strength is 170 pounds. It requires 20 per cent of water for plasticity. The burned brickettes absorb 11.23 per cent of water. Mixed with 10 per cent coal the absorption is 12.5 per cent. Total shrinkage is 4 per cent; the water required for plasticity is 14 per cent. The raw clay has a tensile strength of 77 pounds per square inch; when burned its strength is 222 pounds. When mixed with 10 per cent of Selma clay from Agricultural and Mechanical College campus the absorption is 10 per cent; has a tensile strength, raw, of 111 pounds per square inch, and when burned 105 pounds per square inch; its air shrinkage is only 5 per cent; the amount of water required for plasticity is 14 per cent.

LAFAYETTE COUNTY.

GEOLOGY.

Lafayette County lies wholly within the Wilcox division of the Tertiary. Resting upon the clays and sands of this formation are the Lafayette sand and clays and the Columbia loams. Many outcrops of fine pottery clays are found in the Wilcox in this county. The chemical composition of some of these clays are given in the table below:

TABLE 67.

ANALYSES OF CLAYS FROM THE WILCOX, LAFAYETTE COUNTY.

	No. 1	*No.* 2	*No.* 3	*No.* 4	*No.* 5
Moisture (H_2O)	.69	1.14	1.16	.90	1.64
Volatile matter (CO_2 etc.)	8.20	9.11	10.14	8.35	8.99
Silicon dioxide (SiO_2)	60.00	57.79	51.88	60.40	57.48
Iron oxide (Fe_2O_3)	.75	2.98	3.53	1.32	2.43
Aluminum oxide (Al_2O_3)	27.80	26.03	30.64	27.68	26.94
Calcium oxide (CaO)	1.38	.44	.58	1.08	.78
Magnesium oxide (MgO)	.00	.10	.60	.00	.27
Sulphur trioxide (SO_3)	.20	.24	.00	.00	.20
Total	99.02	97.83	98.53	99.73	98.73

RATIONAL ANALYSES.

Clay base	70.45	65.97	77.65	70.15	68.27
Free silica	17.35	17.85	4.87	17.93	16.15
Fluxing impurities	2.33	3.52	4.71	2.40	3.48

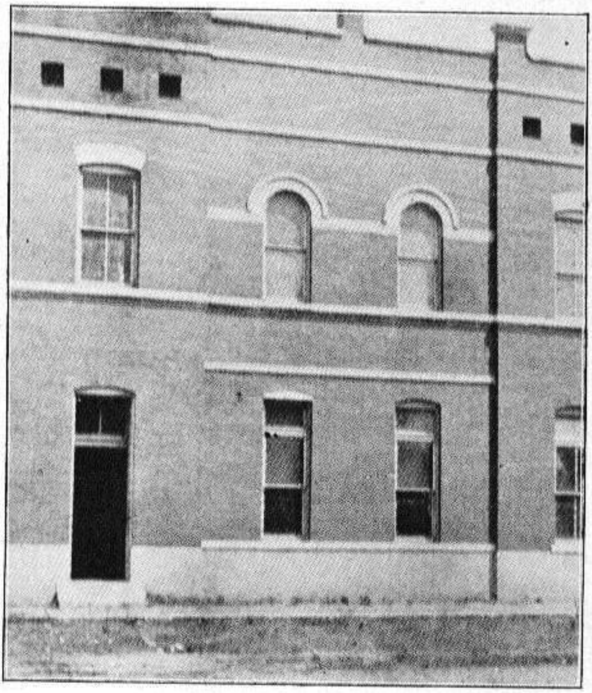
No. 1 is from Oxford, about 3 blocks east of the courthouse. No. 2 is from the street near the colored schoolhouse in Oxford. No. 3 is from Mr. Russell's farm, 3 miles northeast of Oxford. No. 4 is from the Tubbs farm, 3 miles south of Oxford. No. 5 is from the Wyley farm, 6 miles southwest of Oxford.

CLAY INDUSTRY.

College Hill Station.—The Brown loam clay is used at College Hill station, north of Oxford, by the Oxford Brick and Tile Company in the manufacture of pressed brick. The plant was first established south of Oxford near the oil mill, but the thickness of the clay was not adequate and the plant was moved to College Hill station. The plant was established in 1904.

The Brown loam of the county, by proper selection and mixture, may be used in the manufacture of brick by the soft-mud, stiff-mud and dry-press methods. Processes of denudation have removed the loam in many places to such an extent that the thickness is not sufficient to warrant the establishment of brick plants at such points. There are two phases of the loam, a top sandy phase and bottom clayey phase. The latter in some places is very poorly represented

PLATE XXXI.



PUBLIC BUILDING AT DURANT BUILT OF MISSISSIPPI PRESSED BRICK.

and such places are undesirable localities for the manufacture of brick by either the stiff-mud or dry-press method. The white clays of the Wilcox furnish material for the manufacture of white or spotted brick and a fine grade of stoneware.

LAUDERDALE COUNTY.

GEOLOGY.

The bed-rock formations of Lauderdale County are of Tertiary age. The strata represented are the Wilcox and the Claiborne Both of these formations contain beds of clay. The Wilcox (Lagrange) contains beds of pottery clays. The mantle rocks are the Lafayette and the Columbia.

CLAY INDUSTRY.

Lockhart.—The Wilcox clays are utilized at Lockhart in the manufacture of stoneware by the Wedgewood Stoneware Company. The clay is grayish-white and has the following chemical composition:

TABLE 68.

ANALYSIS OF WILCOX STONEWARE CLAY, LOCKHART.

	No. 71
Moisture (H_2O)	3.14
Volatile matter (CO_2 etc.)	7.20
Silicon dioxide (SiO_2)	58.05
Iron oxide (Fe_2O_3)	1.05
Aluminum oxide (Al_2O_3)	27.79
Calcium oxide (CaO)	2.00
Magnesium oxide (MgO)	.25
Total	99.48

RATIONAL ANALYSIS.

Clay base	70.42
Free silica	15.42
Fluxing impurities	3.30

The Lockhart clays have been used in Meridian in the manufacture of brick. The brick are said to be extremely hard and to approach vitrified paving brick in physical properties.

The Columbia loam has been used at Lockhart in the manufacture of brick by Mr. B. R. Brown. The brick are red in color. They are burned in up-draft kilns of the scove type.

A sample of gray clay from the Wilcox formation on Mr. Brown's farm at Lockhart has the following chemical composition:

TABLE 69.

ANALYSIS OF WILCOX CLAY, LOCKHART.	*No. 72a*
Moisture (H_2O)	4.29
Volatile matter (CO_2 etc.)	7.74
Silica (SiO_2)	58.21
Iron oxide (Fe_2O_3)	.83
Aluminum oxide (Al_2O_3)	27.23
Calcium oxide (CaO)	.65
Magnesium oxide (MgO)	.41
Total	99.36
RATIONAL ANALYSIS.	
Clay substance	69.00
Free silica	16.44
Impurities	1.89

Meridian.—At Meridian the Columbia clay is used in the manufacture of brick by the Bonita Manufacturing Company. The clay is prepared by the use of a granulator and tempered in a pug mill. The brick are molded in an end-cut, auger-type, stiff-mud machine. The brick are burned in rectangular updraft kilns. A sample of the tempered clay has the following composition:

TABLE 70.

ANALYSIS OF BRICK CLAY, MERIDIAN.	*No. 93*
Moisture (H_2O)	3.72
Volatile matter (CO_2 etc.)	5.34
Silicon dioxide (SiO_2)	71.58
Iron oxide (Fe_2O_3)	6.95
Aluminum oxide (Al_2O_3)	10.77
Calcium oxide (CaO)	.50
Magnesium oxide (MgO)	.19
Sulphur trioxide (SO_3)	trace
Total	99.05
RATIONAL ANALYSIS.	
Clay substance	27.23
Free silica	55.12
Fluxing impurities	7.64

LEE COUNTY.

GEOLOGY.

The Selma chalk forms the bed-rock of Lee County. It varies in thickness from a few feet on its eastern border to 600 feet on its western border. The surface formations are isolated areas of the Lafayette, and the residual clay of the Selma and the Columbia loam. The clays of these mantle rocks are being utilized in the manufacture of brick at Baldwyn, Saltillo, Verona and Nettleton. Brick were also manufactured at Tupelo.

CLAY INDUSTRY.

Baldwyn.—At Baldwyn, the Baldwyn Brick and Tile Company has opened a pit containing the following layers:

Section of Pit of the Baldwyn Brick & Tile Co., Baldwyn.

	Feet
4. Soil	1
3. Sandy loam or sand	1
2. Plastic red and blue clay	6–8
1. Sand (depth in well)	7

The bottom portion of No. 2 contains small ironstone concretions, "buckshot." The clay from this layer has a total shrinkage of 8 per cent. The raw clay has a tensile strength of 188 pounds per square inch. The soft-burned brickettes have a strength of 130 pounds per square inch. The addition of 20 per cent of water is required for plasticity. When mixed with 10 per cent of coal the clay has a total shrinkage of 6 per cent. Its tensile strength, raw, is 153 pounds. When hard burned it has a strength of 187 pounds per square inch. The amount of water required for plasticity is 20 per cent and the loss in burning 10 per cent. When mixed with 10 per cent of cinders it has a total shrinkage of 6 per cent and requires 16 per cent of water to render it plastic. It loses 8 per cent of its weight in burning. The tensile strength of the raw clay is 138 pounds per square inch. When burned it has a tensile strength of 244 pounds per square inch.

The composition of a sample of the clay is given below:

TABLE 71.

ANALYSIS OF CLAY USED BY THE BALDWYN BRICK AND TILE CO., BALDWYN.

	No. 114
Moisture (H_2O)	3.60
Volatile matter (CO_2)	.04
Silicon dioxide (SiO_2)	72.72
Iron oxide (Fe_2O_3)	3.95
Aluminum oxide (Al_2O_3)	12.55
Calcium oxide (CaO)	6.90
Magnesium oxide (MgO)	.27
Sulphur trioxide (SO_3)	.08
Total	100.11

RATIONAL ANALYSIS.

Clay substance	41.75
Free silica	43.52
Impurities	11.20

Saltillo.—At Saltillo the plant of the Saltillo Brick Manufacturing Company is located about ½ mile south of the Mobile and Ohio Railroad station. This company uses a surface clay in the manufacture of brick by the stiff-mud process. The machine is of the plunger type. No disintegrator or pug mill is used in preparing the clay. The brick are burned in rectangular up-draft kilns. Red is the prevailing color of the burned brick.

The clay in the upper part of the pit is a sandy red clay overlying a sandstone. Both of these layers are probably of Lafayette age. The lower part of the pit is occupied by a more plastic clay which is probably residual Selma, since the latter underlies it. The record of the well at the brick plant shows the thickness of the Selma at this point to be about 330 feet.

The lower clay is too plastic to be used alone. When mixed in the proper proportion with the sandy upper clay it makes a good brick.

Verona.—The Verona Brick and Tile Company's plant is located about ½ mile north of the Mobile and Ohio Railroad station at Verona. Two varieties of surface clay are employed in the manufacture of brick. The bottom of the pit rests upon the Selma chalk. Overlying this bed is a plastic clay which has doubtless been derived from the Selma by decomposition processes. Resting upon the lower clay is a red sandy clay which probably belongs to the Lafayette. In the manufacture of brick these two clays are mixed. The clay is tempered in a horizontal pug mill and molded in a stiff-mud machine of the auger type. The cutter is a side-cut machine. The brick are dried in rack and pallet driers. They are burned in up-draft kilns of the clamp variety.

The auger motion produces laminations in this clay unless it has been carefully tempered. When too large a proportion of the bottom clay is used the difficulties of drying are greatly augmented. Thorough disintegration and mixing are essential to the best results. Gathering the clay too close to the limestone surface may result in inclusions which cause flaws in the brick.

Nettleton.—The Nettleton Manufacturing Company operates a brick plant at Nettleton. The clay used is from a surface deposit consisting of clay, loam and sand. It is probably of Lafayette age for the most part. The total thickness of the formation is about 20 feet, as is shown by well records in the town. The upper portion consists of yellowish loam, below which there is a sandy layer, then a fat jointed clay containing sandy streaks. The clay is prepared by the use of a granulator and a disintegrator. It is then tempered in a pug mill and molded in a soft-mud molding machine, operated by steam power. The molds contain six bricks. They are sanded to prevent the clay from sticking. The brick are placed upon pallets, which are placed on racks under covered sheds. The brick are burned in rectangular up-draft kilns.

LEFLORE COUNTY.

GEOLOGY.

The alluvium of the Yazoo-Mississippi flood plain occupies the surface of the greater part of Leflore County. Beneath this overburden, which has an average thickness of about 50 feet, lies the Claiborne formations. Two rather distinct types of the alluvium are recognizable. The first type is a sandy loam which occupies the surface bordering the streams. The second type is a black, sticky clay which occupies the surface of the inter-stream areas and is called locally "buckshot" land. Vertically the one type may succeed the other within a few feet. The change from one type to the other in vertical and horizontal succession was produced by the shifting or meandering of the depositing stream. When the stream overflows, the water, which passes from the stream's course out over the flooded plain, begins to lose its velocity as it leaves the banks and to drop its load, the heavier particles being deposited first, the finer clay particles being carried to the inter-stream areas.

The clays of this alluvial deposit are used in the manufacture of brick at Greenwood, in Leflore County.

CLAY INDUSTRY.

Greenwood.—The Success Brick and Tile Company of Greenwood is using clay from a pit which has the following stratigraphic relations:

Section of Clay Pit at Greenwood.

	Feet
4. Joint clay, black to gray in color (top)	5
3. Very sandy clay	4
2. Reddish tinged clay	4
1. Blue clay	6

The full thickness of No. 1 is not exposed. Chemical analyses of layers Nos. 1 and 2 were made with the results given in Table No. 72.

TABLE 72.

ANALYSES OF CLAYS, GREENWOOD.

	No. 48	*No.* 98	*No.* 99
Moisture (H_2O)	5.52	3.22	5.75
Volatile matter (CO_2 etc.)	4.75	3.06	6.55
Silicon dioxide (SiO_2)	72.25	73.40	59.32
Aluminum oxide (Al_2O_3)	8.44	6.81	11.45
Iron oxide (Fe_2O_3)	6.56	4.19	10.62
Calcium oxide (CaO)	1.00	1.12	1.50
Magnesium oxide (MgO)	.63	.44	1.37
Sulphur trioxide (SO_3)	.17	.17	2.98
Total	99.32	92.41	99.54
RATIONAL ANALYSES.			
Clay substance	21.35	17.22	26.86
Free silica	59.34	65.40	46.84
Impurities	8.36	5.92	12.48

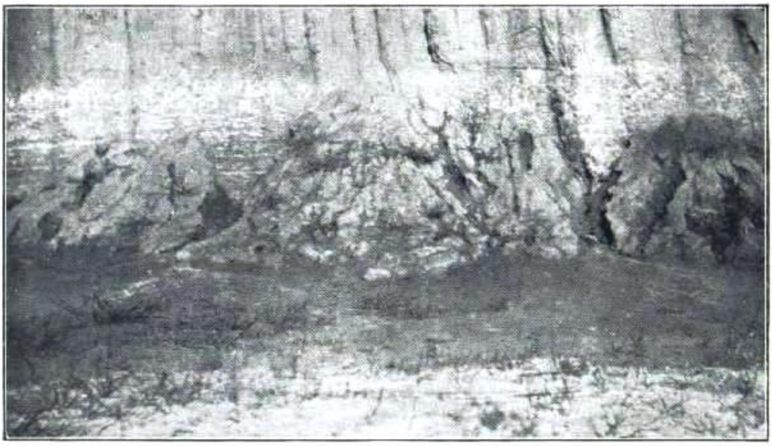
Analysis No. 48 is from bed 1 of the above section; No. 98 is from bed 2, and No. 99 is from bed 3.

The different layers of clay from the above mentioned pit are mixed together in the manufacture of brick. The brick are molded in a stiff-mud auger-type machine with an end-cut. The elevating cars are used in the yard. The clay is prepared in a granulator and pug mill.

Mr. W. O. Bacon also owns and operates a brick plant at Greenwood. He uses a dark, alluvium clay. The thickness of the clay in the pit is about 8 feet; all of the clay is utilized. The brick are molded in a steam-power machine of the soft-mud type. They are dried in sheds in which they are placed on pallets. The brick are burned in up-draft kilns of the clamp type. An analysis of the clay was made with the results shown in No. 99. Some of the clay in the pit is more siliceous than the sample taken.

Minter City.—At Minter City the Cowgill Drain Tile Manufacturing Company uses the alluvium clay in the manufacture of brick and drain tile. Their pit is opened to a depth of 8 feet, the clay being used from

A. BROWN LOAM AND LAFAYETTE OVERLYING THE JACKSON, CANTON CLAY PIT.



B. STRATIFIED LAFAYETTE WITH TALUS, RAILROAD CUT, NEWTON.

top to bottom. The clay varies somewhat in composition from top to bottom of the pit.

Three samples of clay from the pit were analyzed with the following results: No. 55 from near the top, No. 56 from the middle portion, and No. 57 from the bottom

TABLE 73.

ANALYSES OF ALLUVIAL CLAYS, MINTER CITY.

	No. 55	*No. 56*	*No. 57*
Moisture (H_2O)	5.00	4.47	3.75
Volatile matter (CO_2 etc.)	10.81	8.17	7.75
Silicon dioxide (SiO_2)	63.27	62.18	65.66
Iron oxide (Fe_2O_3)	6.32	8.20	5.40
Aluminum oxide (Al_2O_3)	10.43	12.80	10.90
Calcium oxide (CaO)	1.10	1.50	1.35
Magnesium oxide (MgO)	.94	.79	1.01
Sulphur trioxide (SO_3)	.48	.31	.61
Total	98.25	98.42	96.24

RATIONAL ANALYSES.

	No. 55	*No. 56*	*No. 57*
Clay substance	26.36	32.38	27.57
Free silica	52.02	47.13	52.85
Impurities	8.84	10.80	8.38

Clay No. 55 requires the addition of 20 per cent of water to render it plastic. It has a total shrinkage of about 4 per cent. In the raw state it has a tensile strength of 102 pounds per square inch and of 218 pounds when burned. The absorption of the burned brickettes, made from different layers and burned to different degrees of hardness, varies from 5 to 16.41 per cent. The average per cent of absorption for 7 brickettes was 13.06 per cent.

LOWNDES COUNTY.

GEOLOGY.

The subsurface of Lowndes County is formed of Cretaceous strata belonging to the Tuscaloosa, the Eutaw and the Selma divisions. The mantle rock formations are the Lafayette, the Columbia and the residual Selma. Excellent outcrops of the Eutaw are found in the bluffs of the Tombigbee River.

CLAY INDUSTRY.

Columbus.—The Columbus Brick Manufacturing Company, operated by Puckett and Lindamood, was established at Columbus in 1900.

This company operates two plants at Columbus. Both are located upon the second bottom of the Tombigbee River. The clay in the first pit is about 12 feet thick and rests upon sand and gravel. The upper portion is a yellow loam. The lower clay is blue in color, and near the bottom contains some limestone and pebbles.

The clay in the second pit has a yellowish brown layer at the top, then a body of blue and yellow clay with a blue clay at the bottom. The last rests upon a bed of sand. Both common and repressed brick are manufactured. The brick are molded in a stiff-mud end-cut machine. They are dried in open sheds and in steam dryers. The brick are burned in rectangular up-draft kilns of the clamp type.

The Tombigbee second bottom clays furnish the best clays for the manufacture of brick in Lowndes County. They are probably Columbia in age. They rest upon sand and gravels belonging to the Lafayette

MADISON COUNTY.

GEOLOGY.

The Vicksburg and Jackson formations of the Tertiary are the sub-formations of Madison County. The surficial deposits belong to the Lafayette and the Columbia (brown loam phase). The last named formation furnishes the brick material of the county as far as the present development of that industry is concerned.

CLAY INDUSTRY.

Canton.—The Canton Brick Mfg. Company at Canton operates a plant near the Illinois Central Railroad north of the station. Three kinds of clay are exposed in the pit, which exhibits the following stratigraphy:

Section of Clay Pit at Canton.

	Feet
5. Soil	1
4. Brownish loam	4
3. Yellow clay	3
2. Red joint clay	3
1. Blue and yellow clay	...

The clay from No. 1 is residual Jackson. The clay from Nos. 2 and 3 belong to the Lafayette, and that from No. 4 is Columbia.

The lowest clay is very plastic and has a high shrinkage, so that it cannot be used alone. It is either mixed with the clay above it

PLATE XXXIII.

ALLISON CLAY PIT, HOLLY SPRINGS.

or with 10 per cent crushed cinders. The cinders facilitate drying and shorten the time of burning by about 24 hours. The clay from No. 4 has a total shrinkage of 5 per cent. Its tensile strength in the raw state is 140 pounds per square inch. When burned it exhibits a strength of 316 pounds per square inch. It requires 16 per cent of water to render it plastic. It loses 20 per cent in weight in drying and burning. Its absorption is 8.33 per cent.

TABLE 74.

ANALYSES OF CLAYS, CANTON.

	No. 87	*No.* 88	*No.* 89
Moisture (H_2O)	2.87	2.70	4.67
Volatile matter (CO_2)	3.63	3.10	1.95
Silicon dioxide (SiO_2)	79.28	73.22	73.00
Iron oxide (Fe_2O_3)	4.12	5.77	5.47
Aluminum oxide (Al_2O_3)	4.28	9.58	9.53
Calcium oxide (CaO)	.82	2.35	3.32
Magnesium oxide (MgO)	.36	.18	.27
Sulphur trioxide (SO_3)	.42	.40	.70
Total	95.98	97.30	98.91

RATIONAL ANALYSIS.

	No. 87	*No.* 88	*No.* 89
Clay substance	11.33	24.23	24.11
Free silica	72.43	58.57	58.42
Impurities	5.72	8.70	9.76

The clay from No. 2 of the above section is more plastic and shrinks more in drying. It is red in color and has a joint structure. It shrinks in all about 8 per cent and requires the addition of 16 per cent of water. The tensile strength of the raw clay is about 8 per cent and requires the addition of 16 per cent of water to render it plastic. The tensile strength of the raw clay is 102 pounds per square inch. When burned its tensile strength is 275 pounds. Its total loss of weight in drying and burning is 27 per cent, its absorption is 8.33 per cent.

MARSHALL COUNTY.

GEOLOGY.

The subformation of Marshall County is the Wilcox (Lagrange) division of the Tertiary. The formation consists of clays and sand. The clays contain many outcrops of white pottery clays. The mantle-rock formations are the Lafayette sands and clays and the Columbia (brown loam phase). The stratigraphic relations of these formations are presented in the record of the Holly Springs town well.

Record of Holly Springs Well.

	Thickness	Depth
10. Reddish clay (Columbia)	20 feet	20 feet
9. Red sand (Lafayette)	87 "	107 "
8. Sand rock (Lafayette)	1 foot	108 "
7. Clay (Wilcox—Lagrange)	52 feet	160 "
6. Hard sandstone (Wilcox—Lagrange)	.5 foot	160.5 "
5. Clay and sandstone (Wilcox—Lagrange)	139.5 feet	300 "
4. Fine water bearing sand (Wilcox—Lagrange)	40 "	340 "
3. Pipe clay (Wilcox—Lagrange)	13 "	353 "
2. Coarse sand (Wilcox—Lagrange)	4 "	357 "
1. Sticky clay (Porter's Creek?)	43 "	400 "

All layers between No. 8 and No. 1 doubtless belong to the Wilcox (Lagrange). No. 1 may be Porter's Creek (Flatwoods).

CLAY INDUSTRY.

Holly Springs.—The white clays from the Wilcox are being used at Holly Springs in the manufacture of stoneware. Two potteries are operated in this place, one by the Holly Springs Stoneware Company and the other by the Allison Stoneware Company. Both manufacture a general line of stoneware and both manufacture the fire brick used in their own kilns. These brick are manufactured from clays found near Holly Springs. A highly silicious clay is mixed with the white plastic clays which are used in the manufacture of stoneware. The chemical composition of the former is given below. (Bulletin No. 3, A. and M. College, 1905.)

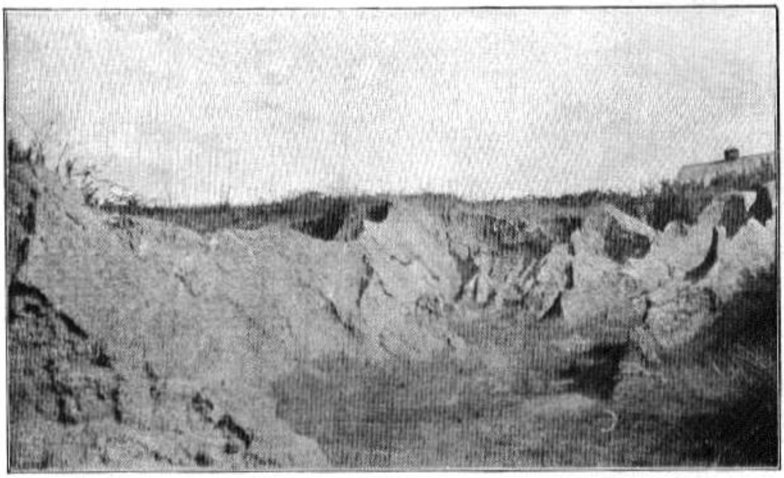
TABLE 75.

ANALYSIS OF FIRE CLAY, HOLLY SPRINGS.

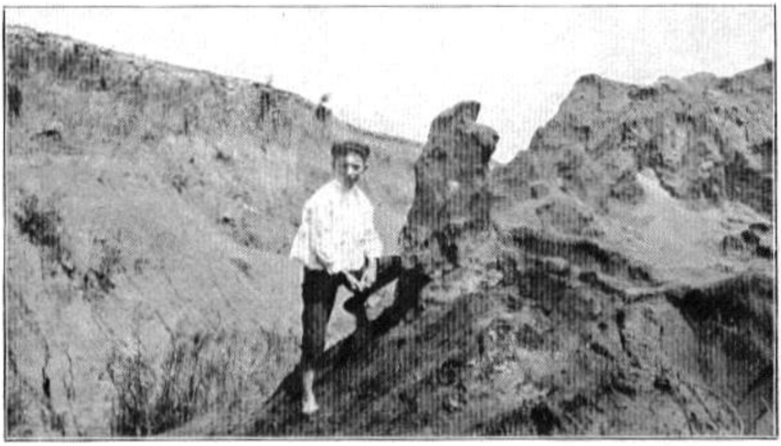
	No. 25a
Moisture (H_2O)	.87
Volatile matter (CO_2 etc.)	1.93
Silicon dioxide (SiO_2)	88.52
Ferric oxide (Fe_2O_3)	1.64
Aluminum oxide (Al_2O_3)	5.26
Calcium oxide (CaO)	.73
Magnesium oxide (MgO)	.13
Sulphur trioxide (SO_3)	.43
Total	99.51

RATIONAL ANALYSIS.

Clay base	13.33
Free silica	80.45
Fluxing impurities	2.50



A. TYPICAL EROSION IN COLUMBIA LOAM, HOLLY SPRINGS.



B. LAFAYETTE OVERLYING WILCOX, HOLLY SPRINGS.

The fire brick manufactured from above mentioned clay have been used for about 25 years in some of the kilns without removal. The clay burns to a slightly pink color which disappears before vitrification, leaving the brick white or light cream in color. The sand grains in the clay are large. Some grains are as large as grains of wheat and of a clear, transparent, quartz variety.

The stoneware clays used by the Holly Springs potteries have the following chemical properties:

TABLE 76.

ANALYSES OF STONEWARE CLAYS, HOLLY SPRINGS.

	No. 20a	*No. 19a*
Moisture (H_2O)	1.51	.94
Volatile matter (CO_2 etc.)	8.07	6.64
Silicon dioxide (SiO_2)	61.69	67.70
Iron oxide (Fe_2O_3)	2.04	3.04
Aluminum oxide (Fe_2O_3)	24.91	19.69
Calcium oxide (CaO)	.34	1.06
Magnesium oxide (MgO)	.83	.58
Sulphur trioxide (SO_3)	.20	.19
Total	99.59	99.84

RATIONAL ANALYSIS.

Clay base	63.13	49.90
Free silica	23.47	37.49
Fluxing impurities	3.21	4.68

No. 20a is from the Allison clay pit, and No. 19a is from the Holly Springs Stoneware Company's pit. These pits are only a few rods apart and are located about 1¼ miles east of Holly Springs.

The Holly Springs Brick Mfg. Company (Erby Bros.) uses the brown loam clay in the manufacture of brick by the soft-mud process. The brick are molded by hand, dried in the open air and burned in a rectangular up-draft kiln. The clay varies in composition from a sandy loam at the top to a plastic joint clay in the bottom of the pit. The thickness of the deposit is 5 to 6 feet. A sample of clay taken from near the bottom of the pit was analyzed with the following results:

TABLE 77.

ANALYSIS OF BRICK CLAY, HOLLY SPRINGS.	*No.* 111
Moisture (H_2O)	1.08
Volatile matter (CO_2 etc.)	2.11
Silicon dioxide (SiO_2)	80.76
Iron oxide (Fe_2O_3)	4.50
Aluminum oxide (Al_2O_3)	8.50
Calcium oxide (CaO)	1.50
Magnesium oxide (MgO)	.45
Sulphur trioxide (SO_3)	.04
Total	98.94
RATIONAL ANALYSIS.	
Clay substance	21.50
Free silica	70.67
Impurities	6.49

The amount of water which the above mentioned clay requires for plasticity is 19 per cent. It has a total shrinkage of 3 per cent. The raw brickettes have a tensile strength of 42 pounds, and when soft burned the strength is 45 pounds per square inch. The loss of weight in water-smoking and burning is 16 per cent.

MONTGOMERY COUNTY.

GEOLOGY.

The subformations of Montgomery County are the Wilcox (Lagrange) and the Tallahatta buhrstone (Silicious Claiborne). The surface formations belong to the Lafayette and the brown loam phase of the Columbia, which is widely distributed over the county.

CLAY INDUSTRY.

Winona.—The Columbia formation is used at Winona in the manufacture of brick. The Jessty Brick and Lumber Company manufactures brick by the dry-press process. They use a mixture of brown loam clay and a white clay from the Lafayette. The clay pit from which the white clay is taken is from an outcrop on the Southern Railroad about 1 mile west of town. It burns white and leaves white specks on the surface of the brick, presenting an attractive appearance. It also reduces the shrinkage of the brown clay and raises its fusion point.

The brown loam clays and the Wilcox clays are the sources of the principal brick material of this county.

MONROE COUNTY.

GEOLOGY.

The substrata of Monroe County belong to the Tuscaloosa, the Eutaw (Tombigbee), and the Selma. The surficial formations are the Lafayette sands and clays and the Columbia loams. The second bottom of the Tombigbee River, which crosses the county from north to south, is made up of sand and gravel, overlying which is a bed of clay grading into a loam at the top. The river has cut its trench into the soft rock of the Eutaw, and for the greater part of its distance marks the boundary between the Eutaw and the Selma; the higher Eutaw bluff on the west side of the stream being capped with the Selma. When not removed by erosion these higher bluffs are mantled with Lafayette and Columbia.

CLAY INDUSTRY.

Aberdeen.—At Aberdeen, just south of the waterworks, the Lafayette rests upon the eroded surface of the Eutaw. The line of contact is quite clearly marked in this instance by a thin layer of friable, whitish sandstone. The section exposed is as follows:

Section at Aberdeen.	Feet
2. Orange colored sand with some clay lenses, crossbedded with some joint clay at the top	12
1. Greenish sand (Eutaw)	20

At a lower horizon, on the river bank south of the bridge, about 30 feet of bluish gray sand containing some clay is exposed. In places the sand contains fossils and micaceous concretions containing iron pyrites. There are also some sandstone concretions, and in one exposure a rather persistent layer of friable sandstone from 1 to 2 feet in thickness. The clay pit belonging to the Aberdeen Sand-Lime Brick Company is located on the second bottom of the Tombigbee River. The clay is not being used at the present time, as the company is engaged in the manufacture of sand-lime brick. The old clay pit exhibits the following section:

Old Clay Pit at Aberdeen.	Feet
3. Sandy loam soil	1
2. Joint clay, blue in places	7
1. Sand	...

The clay from No. 2 has a tensile strength in the raw state of 87 pounds per square inch. It has a total shrinkage of 10 per cent and loses 11 per cent in weight in being water-smoked and burned. When mixed with 10 per cent coal the clay has a total shrinkage of 6 per cent and requires 17 per cent of water to render it plastic. Raw, it has a tensile strength of 140 pounds per square inch, and burned the strength is 263 pounds per square inch. Loss of weight in burning is 10 per cent. The burned brickettes have an absorption of 12.24 per cent. When mixed with 10 per cent of cinders its shrinkage is 6 per cent. In the raw state its strength is 175 pounds; burned, 300 pounds. A sample of the clay has the following chemical composition:

TABLE 78.

ANALYSIS OF JOINT CLAY, ABERDEEN.

	No. 103
Moisture (H_2O)	4.95
Volatile matter (CO_2 etc.)	4.92
Silicon dioxide (SiO_2)	71.13
Iron oxide (Fe_2O_3)	7.75
Aluminum oxide (Al_2O_3)	9.12
Calcium oxide (CaO)	.42
Magnesium oxide (MgO)	.63
Sulphur trioxide (SO_3)	.08
Total	99.00

RATIONAL ANALYSIS.

Clay substance	23.07
Free silica	60.41
Impurities	8.88

Amory.—At Amory the Tombigbee second bottom clay is used by two companies in the manufacture of brick. The stratigraphy of the formation at this point is shown by the following well record:

General Section of Amory Wells.

	Thickness	Depth
Surface loam and clay (Columbia?)	15 feet	15 feet
Gravel, water-bearing (Lafayette?)	25 "	40 "
Blue sand (Eutaw)	100 "	140 "
Sand, water-bearing (Eutaw)	50 "	190 "

The L. H. Tubbs Brick Manufacturing Company began the manufacture of brick at Amory in 1894. They use a stiff-mud machine of the plunger type.

Section of Clay Pit, Amory.

	Feet
4. Sandy soil	1
3. Yellowish loam	3
2. Joint clay, bluish and reddish tints	7
1. Sand and gravel	5

There is no distinct line of separation between 2 and 3. The clay of No. 2 requires 14 per cent of water for plasticity. It has a total shrinkage of 6 per cent. Its tensile strength, raw, is 100 pounds per square inch, and burned, it has a strength of 220 pounds. It absorbs 11.86 per cent of water in the soft burned stages. Mixed with 10 per cent of coal its physical properties are: Total shrinkage, 6⅔ per cent; tensile strength, raw, 150 pounds; burned, 273 pounds. Mixed with 10 per cent of cinders, its physical properties are: Shrinkage, 5 per cent; tensile strength, raw, 155 pounds; burned, 300 pounds per square inch.

The chemical composition of a sample of No. 3 is given below:

TABLE 79.

ANALYSIS OF YELLOW LOAM CLAY, AMORY.

	No. 94
Moisture (H_2O)	5.20
Volatile matter (CO_2 etc.)	5.10
Silicon dioxide (SiO_2)	71.04
Iron oxide (Fe_2O_3)	7.92
Aluminum oxide (Al_2O_3)	9.27
Calcium oxide (CaO)	.87
Magnesium oxide (MgO)	.31
Sulphur trioxide (SO_3)	trace
Total	99.71

RATIONAL ANALYSIS.

Clay substance	23.45
Free silica	56.86
Fluxing impurities	9.10

Mr. C. C. Camp has operated a brick plant at Amory since 1896. In 1904 he installed new machinery. The clay is molded in a stiff-mud machine of the auger type. The die is a double bar die. The cutter is an automatic end-cut machine. The clay pit is near that of the other yard, and the stratigraphic conditions are similar. The brick are burned in rectangular up-draft kilns.

NEWTON COUNTY.

GEOLOGY.

The southwestern corner of Newton County is underlain by the Jackson formation. The remainder of the county is underlain by the Claiborne. The mantle rocks belong to the Lafayette and the Columbia and residual clays form the bed-rock formations.

CLAY INDUSTRY.

Newton.—The surface formations are used in the manufacture of brick at Newton. The Hancock Brick Company operates a plant south of the Alabama and Vicksburg Railroad, west of town. The brick are dried under a large shed open at both ends. They are burned in rectangular up-draft kilns.

The clay is reddish with a yellow loam overlying it. The absorption of the clay in the bottom layer is 9.52 per cent, and the absorption of that in the top layer is 13.79 per cent.

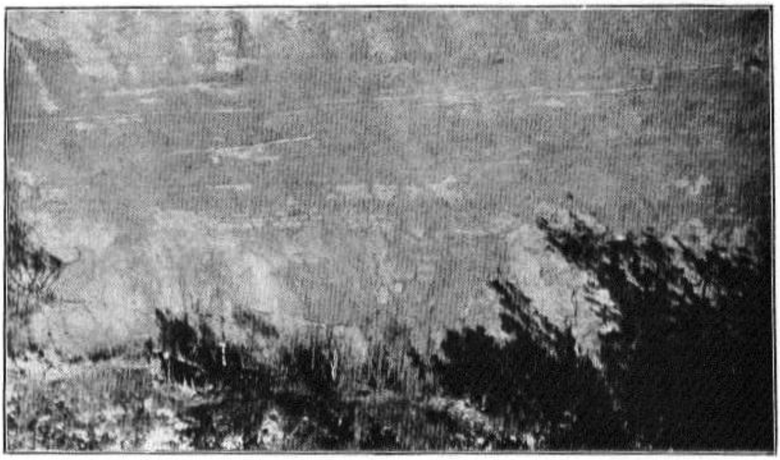
In a railroad cut on the Mobile, Jackson and Kansas City Railroad, south of town, there is an exposure of the following formations:

Section of Surface Formations at Newton.

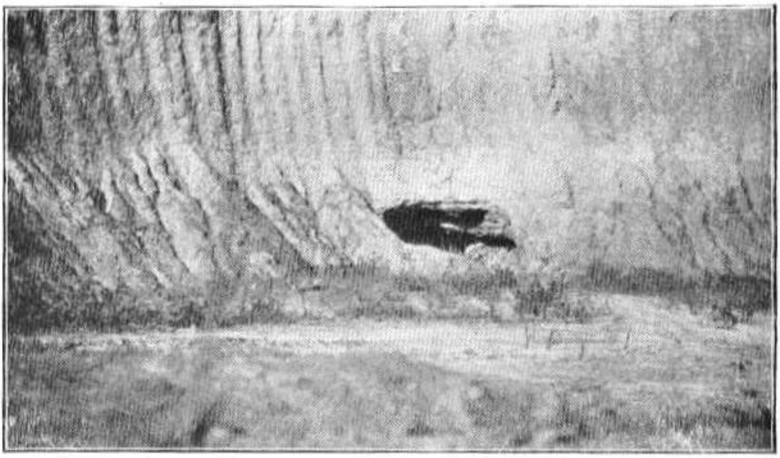
	Feet
3. Yellow loam with some pebbles	6–8
2. Orange sand with silicious pebbles	6–10
1. Red sand with white clay partings	6–8

No. 1 contains partings of clay and has an irregular stratification. In some places the partings are in the nature of very fine white lines, as though they had been drawn by the painter's brush or a grainer. The top of this layer is somewhat conglomerate, small masses of clay being mixed with the sand.

The pebbles of No. 2 are more numerous at the top. No. 3 appears to be a weathered product of No. 2. If Nos. 1 and 2 are Lafayette, as seems probable, then No. 3 doubtless represents the Columbia.



A. CLAY PARTINGS IN LAFAYETTE SANDS, NEWTON.



B. EROSION IN LAFAYETTE SANDS BY UNDERGROUND WATER, NEWTON.

TABLE 80.

ANALYSES OF CLAYS, NEWTON.

	No. 91	*No.* 92
Moisture (H_2O)	1.52	2.32
Volatile matter (CO_2 etc.)	3.08	3.20
Silicon dioxide (SiO_2)	84.54	82.82
Iron oxide (Fe_2O_3)	4.12	3.75
Aluminum oxide (Al_2O_3)	.60	7.05
Calcium oxide (CaO)	5.83	.50
Magnesium oxide (MgO)	.22	.17
Sulphur trioxide (SO_3)	.23	.00
Total	100.14	99.41

RATIONAL ANALYSIS.

Clay substance	1.50	17.83
Free silica	83.63	71.54
Impurities	10.40	4.42

No. 91 is from the Hancock pit; No. 92 is from an outcrop ½ mile west. The physical properties of No. 91 are: Water required for plasticity, 20 per cent; total shrinkage, 10 per cent; tensile strength of raw clay, 87 pounds per square inch; burned, 150 pounds per square inch. No. 92 has the following physical properties: Total shrinkage, 1 per cent; water required for plasticity, 17 per cent; tensile strength, raw, 37 pounds; burned, 53 pounds per square inch. It is deficient in bonding matter.

NOXUBEE COUNTY.

GEOLOGY.

The subsurface of Noxubee County is the Selma and the Ripley divisions of the Cretaceous, and the Wilcox. The surficial formations are isolated outcrops of the Lafayette, the Columbia and the residual Selma clays.

CLAY INDUSTRY.

Macon.—The surface clays are used at Macon by the Cline Brick Manufacturing Company in the manufacture of brick by the soft-mud process. The clay is tempered in a ring pit. The brick are molded by hand and burned in rectangular up-draft kilns. In the clay pit, about 8 feet of clay rests upon the Selma chalk. The clay in the upper portion of the bed is red in color and of a coarse, sandy texture. It is probably Lafayette. The lower portion of the clay is more plastic and cannot be used alone on account of sticking in molds in molding, and of checking and cracking in drying.

The Selma chalk contains concretions of iron pyrites which, upon exposure to the atmosphere, oxidize producing ferrous sulphate and sulphuric acid which act upon the limestone. The limestone being dissolved, the insoluble clay which it contains is left behind, and accumulates to form a thick bed. The clay immediately overlying the limestone is greenish in color, a condition probably due to the presence of ferrous sulphate. Concretions of iron oxide also occur along the line of contact between the clay and the limestone. These are formed by the oxidation of the iron pyrites nodules.

The following analyses are of two samples of the Selma chalk from Macon:

TABLE 81.

ANALYSES OF SELMA LIMESTONES No. 100, MACON.

	No. 1	*No.* 2
Moisture (H_2O)	1.25	.95
Volatile matter (CO_2 etc.)	36.28	35.15
Silicon dioxide (SiO_2)	9.18	13.03
Aluminum oxide (Al_2O_3)	.00	5.25
Iron oxide (Fe_2O_3)	3.50	2.18
Calcium oxide (CaO)	45.92	41.56
Magnesium oxide (MgO)	.84	.36
Sulphur trioxide (SO_3)	.34	.64
Total	97.31	99.12

No. 2 was collected by A. F. Crider from Macon Bluff on the Tombigbee River.

The greenish colored clay overlying the limestone has the following chemical constituents:

TABLE 82.

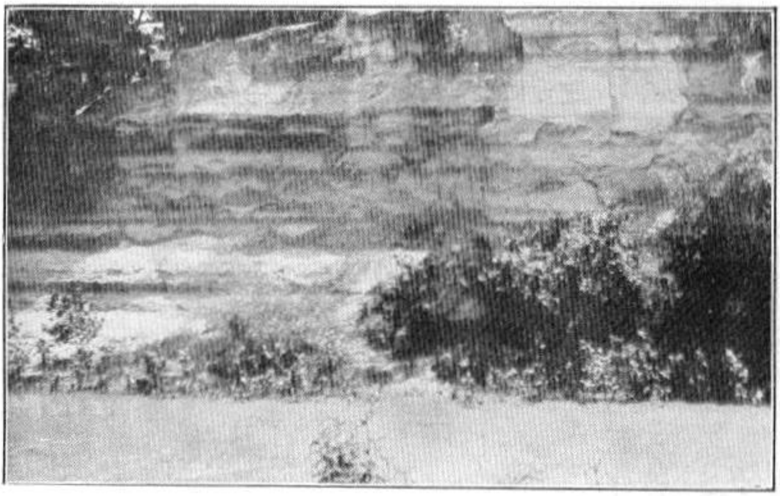
ANALYSIS OF RESIDUAL SELMA CLAY, MACON.

	No. 101
Moisture (H_2O)	11.60
Volatile matter (CO_2 etc.)	10.00
Silicon dioxide (SiO_2)	50.51
Aluminum oxide (Al_2O_3)	17.31
Iron oxide (Fe_2O_3)	5.75
Calcium oxide (CaO)	2.70
Magnesium oxide (MgO)	1.40
Sulphur trioxide (SO_3)	.21
Total	99.48

RATIONAL ANALYSIS.

Clay substance	43.79
Free silica	30.16
Impurities	10.06

A. RESIDUAL CLAY AND LAFAYETTE OVERLYING SELMA CHALK, MACON.



B. SELMA CHALK ON NOXUBEE RIVER, MACON.

There is but little doubt that the above mentioned clay has been derived from the Selma limestone, the decomposition of which was influenced by the decomposition of the iron pyrites present in the limestone. This bottom clay is too fat to be used in the manufacture of brick. It sticks to the molds when used in the soft-mud machine and cracks in drying when used in the stiff-mud machine. The Lafayette clay lying above the residual Selma is much leaner and contains a high per cent of iron. The chemical analysis of the Lafayette clay from Macon follows:

TABLE 83.

ANALYSIS OF CLAY, MACON.

	No. 77
Moisture (H_2O)	7.59
Volatile matter (CO_2 etc.)	7.75
Silicon dioxide (SiO_2)	57.25
Iron oxide (Fe_2O_3)	18.95
Aluminum oxide (Al_2O_3)	6.17
Calcium oxide (CaO)	1.05
Magnesium oxide (MgO)	.95
Sulphur trioxide (SO_3)	.21
Total	99.92

RATIONAL ANALYSIS.

Clay substance	15.61
Free silica	50.00
Impurities	27.16

In the manufacture of brick the best results are to be obtained by mixing the Lafayette clay with the Selma residual clay. Near the railroad station at Macon there is a residual clay which is probably derived from the Flatwoods clay. The grain of the clay is fine and it has shrinkage of 15 per cent. The tensile strength of the raw clay is 87 pounds; the burned clay has a strength of 78 pounds; the water required for plasticity is 18 per cent; the amount of absorption of the burned clay is 8.69 per cent. The absorption of the Lafayette clay is 11.42 per cent.

OKTIBBEHA COUNTY.

GEOLOGY.

The bed-rock formations of Oktibbeha County belong to the Cretaceous and the Tertiary periods. The Selma chalk and a few outliers of the Ripley are present in the eastern part of the county. The western part of the county is underlain by the Wilcox-Eocene. The mantle deposits are Lafayette, residual Selma and Columbia. The last two are well represented in the western part of the county, but only by isolated outcrops in the eastern half. The residual Selma clay and the Columbia are used in the manufacture of brick in Starkville.

CLAY INDUSTRY.

Starkville.—At Starkville the Howard Brick Manufacturing Company uses a clay which rests directly upon the surface of the Selma chalk. The greater part of the clay deposit was formed doubtless by the decomposition of the limestone. The limestone immediately below the clay is partly decomposed and contains 19.30 per cent of clay. The following analyses show the composition of the limestone and the clay immediately above:

TABLE 84.

ANALYSES OF LIMESTONE AND CLAY, STARKVILLE.

	No. 40	*No.* 41
Moisture (H_2O)	.85	4.75
Volatile matter (CO_2 etc.)	23.15	2.27
Silicon dioxide (SiO_2)	20.60	65.30
Iron oxide (Fe_2O_3)	4.62	12.18
Aluminum oxide (Al_2O_3)	7.63	12.63
Calcium oxide (CaO)	41.81	1.50
Magnesium oxide (MgO)	.81	.63
Sulphur trioxide (SO_3)	.25	.25
Total	99.72	99.51

RATIONAL ANALYSIS.

Clay substance	19.30	31.95
Free silica	11.73	51.45
Impurities	47.49	14.18

No. 40—Selma limestone.
No. 41—Residual Selma clay.

Samples of clay and limestone taken from another part of the pit have the following composition:

TABLE 85.

ANALYSES OF SELMA LIMESTONE AND OVERLYING CLAY, STARKVILLE.

	No. 9	*No.* 10
Moisture (H_2O)	.75	.55
Volatile matter (CO_2)	28.20	.97
Silicon dioxide (SiO_2)	17.03	76.60
Iron oxide (Fe_2O_3)	3.33	2.00
Aluminum oxide (Al_2O_3)	21.00	18.37
Calcium oxide (CaO)	29.29	.90
Magnesium oxide (MgO)	.00	.00
Sulphur trioxide (SO_3)	.72	.70
Potassium oxide (K_2O)	.00	.00
Sodium oxide (Na_2O)	.00	.00
Total	100.32	100.09
RATIONAL ANALYSIS.		
Clay substance	53.13	46.47
Free silica	7.66	55.00
Impurities	33.34	3.60

No. 9—Selma limestone.
No. 10—Residual Selma clay.

The sample of limestone was taken from immediately below the clay. It contains 53.13 per cent of clay substance, or is more than half clay. The clay sample was from near the bottom of the clay deposit. The bottom clay is usually too plastic, and has too high a shrinkage to be used alone in the manufacture of brick. The proper texture and shrinkage is obtained by mixing the more sandy top clay with the bottom clay. The top clay contains considerable non-plastic material. The clay immediately overlying the limestone requires careful selection to prevent defects in the brick, because it contains in places nodules or concretions of limestone and ironstone. These nodules are liable to break the wires of the cutter, and to produce cavities or fused masses in the brick. The limestone nodules represent the more insoluble portions of the chalk, such as the casts of shells and the concretions of which fossils form the nuclei. The iron nodules were formed doubtless by the oxidation of concretionary nodules of iron pyrites, which are not of uncommon occurrence in the chalk.

The oxidation of the pyrite produces sulphuric acid, which attacks the calcium carbonate, forming calcium sulphate (gypsum), which is soluble in water and thus may be dissolved out as the clay weathers. The chemical reaction is as follows:*

$$FeS_2 + 6O = FeSO_4 + SO_2 \text{ or}$$
$$FeS_2 + 3O = H_2O + FeSO_4 + H_2S$$

---

*Van Hise, Metamorphism, p. 214.

The iron sulphate ($FeSO_4$) may be changed to iron oxide, limonite, by oxidation and hydration:

$$FeSO_4 + 20 + 7H_2O = 2Fe_2O_3 + 3H_2O + 4H_2SO_4$$

The sulphuric acid (H_2SO_4) then reacts with the calcium carbonate to produce calcium sulphate:

$$CaCO_3 + H_2SO_4 = CaSO_4 + H_2O + CO_2$$

or the iron sulphate may react directly in the following manner:

$$FeSO_4 + CaCO_3 = CaSO_4 + FeCO_3$$

The sulphuric acid, together with the action of the acids produced by decaying vegetation, dissolve out the limestone and cause the accumulation of the insoluble clay residue.

Agricultural and Mechanical College.—The residual Selma clay also occurs on the campus of the State Agricultural and Mechanical College. From an excavation made during the construction of the steam pipe tunnel, the following samples were taken from a point immediately in front of the Mess Hall. The analyses of these samples are recorded below:

TABLE 86.

ANALYSES OF LIMESTONE AND CLAYS, AGRICULTURAL COLLEGE.

	No. 64	*No. 65*	*No. 66*	*No. 67*	*No. 68*	*No. 69*
Moisture (H_2O)	1.50	6.02	5.50	5.00	4.46	5.36
Volatile matter (CO_2)	24.50	6.50	5.00	4.35	5.65	2.78
Silicon dioxide (SiO_2)	29.98	63.35	67.60	69.35	66.85	66.51
Aluminum oxide (Al_2O_3)	5.60	13.70	12.55	12.65	12.05	15.10
Iron oxide (Fe_2O_3)	5.45	7.90	7.60	6.80	7.07	7.00
Calcium oxide (CaO)	31.62	.80	.80	.50	1.62	1.00
Magnesium oxide (MgO)	.14	.60	.78	.58	.18	.58
Sulphur trioxide (SO_3)	.21	.34	.17	.42	.08	.31
Total	99.00	99.21	100.00	99.65	97.96	98.64

RATIONAL ANALYSIS.

Clay substance	14.16	34.66	31.75	32.00	30.48	38.20
Free silica	23.40	47.24	43.85	54.48	48.42	48.76
Impurities	37.42	9.64	9.35	8.30	8.95	8.89

No. 64 is the limestone or chalk immediately underlying the clay. Nos. 65 to 69, inclusive, are samples of clay from the tunnel taken in order from bottom to top of the first 5 feet of clay, one sample being taken from each successive foot. The absorption of No. 64 is 18 per cent. Clay No. 65 has a total shrinkage of 8 per cent; it requires 16 per cent of water for plasticity; it has a tensile strength, raw, of 133 pounds per square inch, and when burned has a strength of 146 pounds per square inch. It loses 12 per cent in weight in being burned, and has an absorption of 7.27 per cent. When mixed with 10 per cent of coal it requires 14 per cent of water to render it plastic. The loss of weight in the soft-burned brickettes is 15 per cent. It has a total shrinkage of 3⅓ per cent. The tensile strength of the raw clay is 119 pounds per square inch. When burned it has a strength of 150 pounds per square inch. Its absorption is 12.24 per cent. When mixed with 10 per cent of cinders the clay has a total shrinkage of 3⅓ per cent; requires 15 per cent of water for plasticity; has a tensile strength, raw, of 72 pounds per square inch, and when burned a strength of 153 pounds per square inch. Its loss of weight in burning is 14 per cent. Its absorption is 12.9 per cent.

Clay No. 66 has a total shrinkage of 6 per cent. It requires 15 per cent of water for plasticity. The loss in burning is 12 per cent. The tensile strength of the raw clay is 94 pounds per square inch. When burned it has a strength of 250 pounds per square inch. Its absorption is 9.8 per cent.

Clay No. 67 has a total shrinkage of 5½ per cent. It requires 14 per cent of water for plasticity. The loss of weight in burning is 14 per cent. The raw clay has a tensile strength of 94 pounds per square inch and when burned its strength is 240 pounds per square inch. Its absorption is 9.4 per cent. When mixed with 10 per cent of coal the clay requires 16 per cent of water; shrinks 3⅓ per cent; has a tensile strength, raw, of 77 pounds and soft-burned of 106 pounds per square inch. When mixed with 10 per cent of cinders it requires 14 per cent of water; has a total shrinkage of 3⅓ per cent. The raw clay has a strength of 66 pounds and the burned clay a strength of 131 pounds per square inch. Its absorption is 15.09 per cent.

Clay No. 68 requires 16 per cent of water; it has a total shrinkage of 5 per cent; its loss of weight in burning is 13 per cent; its tensile strength, raw, is 133 pounds per square inch. When burned it has a strength of 312 pounds per square inch. Its absorption is 9.61 per cent.

Clay No. 69 requires 17 per cent of water for plasticity. The total shrinkage of the clay is 5 per cent. The tensile strength of the raw clay is 105 pounds per square inch. The strength of the burned clay is 333 pounds per square inch. Its absorption is 13.55 per cent. The average absorption of all except No. 64 is 10.12 per cent.

In an excavation for a sewer line a few rods south of the above mentioned tunnel, a bed of clay was exposed resting upon the surface of the chalk. A sample of the chalk and one sample from the bottom and one sample from the middle of the clay deposit were taken and analyzed with the following results:

TABLE 87.

ANALYSES OF LIMESTONE AND CLAYS, AGRICULTURAL COLLEGE.

	No. 35	*No.* 36	*No.* 37
Moisture (H_2O)	.81	4.06	2.95
Volatile matter (CO_2 etc.)	28.61	8.60	10.90
Silica (SiO_2)	27.05	60.43	56.97
Iron oxide (Fe_2O_3)	5.45	10.05	10.40
Aluminum oxide (Al_2O_3)	6.45	13.15	15.09
Calcium oxide (CaO)	30.21	2.13	1.00
Magnesium oxide (MgO)	.00	.54	1.25
Sulphur trioxide (SO_3)	.32	.36	.34
Total	98.90	99.32	98.90
RATIONAL ANALYSIS.			
Clay substance	16.31	33.26	38.17
Free silica	20.47	45.97	39.23
Impurities	35.93	12.08	12.99

No. 35—Selma chalk.
Nos. 36 and 37—Residual Selma clays.

Maben.—The Maben Brick Manufacturing Company, of Maben, began the manufacture of brick in 1905. Two kinds of clay are used. One kind is a white clay from the B. F. Sanders farm, a few miles west of Maben. The clay belongs to the Wilcox (Lagrange) division of the Lignitic. It remains white when burned. Its shrinkage is very low. The chemical composition of a sample is given below:

TABLE 88.

ANALYSIS OF WHITE CLAY, MABEN.

	No. 59*a*
Moisture (H_2O)	1.47
Volatile matter (CO_2 etc.)	9.24
Silica (SiO_2)	59.82
Iron oxide (Fe_2O_3)	1.26
Aluminum oxide (Al_2O_3)	27.19
Calcium oxide (CaO)	.49
Magnesium oxide (MgO)	.37
Sulphur trioxide (SO_3)	.31
Total	100.15
RATIONAL ANALYSIS.	
Clay substance	68.80
Free silica	18.21
Impurities	2.43

The above mentioned plant also uses a surface clay belonging to the yellow loam phase of the Columbia. The clay pit has the following stratigraphy:

Section of Clay Pit, Maben.

	Feet
2. Sandy loam, gray to yellow........................	2
1. Clay, gray in color................................	6

In the bottom of the pit there are numerous ironstone concretions.

The brick burned from the surface clay vary in color from bright red to chocolate. They are molded in a stiff-mud machine of the auger type. The clay is prepared in a granulator and disintegrator and tempered in a horizontal pug mill. The brick are burned in rectangular up-draft clamp kilns. The brick are dried by being packed on pallets and placed on racks in covered sheds.

PANOLA COUNTY.

GEOLOGY.

The Wilcox forms the subsurface of Panola County. The mantle rocks consist of the alluvial deposits of the Yazoo basin, the Loess, the Lafayette and the Columbia. The clay from the last named formation is used in the manufacture of brick.

CLAY INDUSTRY.

Sardis.—At Sardis the clay from the Columbia is employed in the manufacture of brick by the Buchanan Brick Manufacturing Company. The brick are molded by the soft-mud process. The clay is prepared in a disintegrator and tempered in a pug mill. It is then molded in a soft-mud machine which is operated by steam power. The brick are burned in rectangular up-draft kilns.

The clay in the pit has a thickness of 8 to 10 feet. The upper portion is much leaner than the basal portion. The following analysis gives the composition of the latter:

TABLE 89.

ANALYSIS OF COLUMBIA CLAY, SARDIS.	*No.* 80
Moisture (H_2O)	2.90
Volatile matter (CO_2 etc.)	2.42
Silicon dioxide (SiO_2)	74.41
Iron oxide (Fe_2O_3)	5.37
Aluminum oxide (Al_2O_3)	12.22
Calcium oxide (CaO)	1.40
Magnesium oxide (MgO)	1.25
Sulphur trioxide (SO_3)	.03
Total	100.00

RATIONAL ANALYSIS.	
Clay substance	30.91
Free silica	60.04
Impurities	8.05

The physical properties of the Sardis clay are as follows: The clay requires 18 per cent of water to render it plastic. It has a total shrinkage of 6 per cent. The raw brickettes show a tensile strength of 111 pounds per square inch, and when burned they have a strength of 140 pounds per square inch. The loss in burning is 5 per cent of the weight and the absorbtive power of the burned clay is 14.51 per cent. The minimum amount of bonding power is exhibited by the clay from the upper portion of the pit. The basal clay requires the addition of non-plastic material for the manufacture of soft-mud brick.

Batesville.—No brick are being manufactured at Batesville at present. No doubt the Brown loam clays which are well represented there could be utilized with the same degree of success that has been attained in other parts of the county. The unweathered Loess which lies at the base of the Columbia cannot be used alone in the manufacture of brick. It lacks bonding power. The following analysis is of a sample of unweathered, or but slightly weathered, Loess from Batesville.

TABLE 90.

ANALYSIS OF UNWEATHERED LOESS, BATESVILLE.	*No.* 78
Moisture (H_2O)	1.81
Volatile matter (CO_2)	3.20
Silicon dioxide (SiO_2)	75.11
Iron oxide (Fe_2O_3)	5.50
Aluminum oxide (Al_2O_3)	10.70
Calcium oxide (CaO)	.60
Magnesium oxide (MgO)	.47
Sulphur trioxide (SO_3)	.00
Total	97.39

RATIONAL ANALYSIS.

Clay substance	27.07
Free silica	62.53
Impurities	6.57

The aluminum in analysis No. 78 is probably largely contained in undecomposed feldspars. This fact undoubtedly accounts for the low bonding power of the clay. The best residual clays from this formation are to be found in areas where the Loess has not been subjected to rapid erosion. Second bottom deposits usually afford the best clays.

The physical properties of the above mentioned Loess clay are as follows: It requires 18 per cent of water for plasticity. The air shrinkage is 4 per cent. The raw clay has a maximum tensile strength of 72 pounds per square inch, and the hard-burned brickettes show a maximum strength of 111 pounds per square inch. The color of the burned clay is red. The clay cracks badly when dried rapidly and is deficient in bonding power.

PONTOTOC COUNTY.

GEOLOGY.

Pontotoc County is crossed from north to south by the following formations, taking them in order from east to west: Selma chalk, Ripley and Wilcox. The surficial formations belong to the Lafayette and the Columbia.

CLAY INDUSTRY.

Pontotoc.—The Columbia clay is used at Pontotoc in the manufacture of brick. The plant is operated by the Austin Brick Manufacturing Company. The following is an analysis of a sample of the clay used:

TABLE 91.

ANALYSIS OF COLUMBIA CLAY, PONTOTOC.

	No. 105
Moisture (H_2O)	2.13
Volatile matter (CO_2 etc.)	3.70
Silicon dioxide (SiO_2)	77.57
Iron oxide (Fe_2O_3)	6.25
Aluminum oxide (Al_2O_3)	7.25
Calcium oxide (CaO)	.50
Magnesium oxide (MgO)	1.90
Sulphur trioxide (SO_3)	.17
Total	99.47

RATIONAL ANALYSIS.

Clay substance	18.34
Free silica	69.05
Impurities	8.82

Clay No. 105 has an absorption of 12.96 per cent. Its total shrinkage is 6⅔ per cent. It requires 15 per cent of water for plasticity. The tensile strength of the raw clay is 60 pounds per square inch, and of the burned clay 80 pounds per square inch.

PRENTISS COUNTY.

GEOLOGY.

The Subcarboniferous forms the bed-rock of a small part of the southeastern portion of Prentiss County. The Tuscaloosa clays outcrop along the eastern part of the county. The central portion is occupied by the Eutaw formation, and the western portion, with the exception of the northwestern corner, by the Selma chalk. The Ripley occupies a small area west of the Selma. The mantle rock formations are the residual clays of these various bed-rocks, the Lafayette and the Columbia loams. The clays of these surface formations are being used in the manufacture of brick and tile at Booneville and at Thrasher.

CLAY INDUSTRY.

Booneville.—The Booneville Brick and Tile Company of Booneville use the clay from a pit in which the following stratigraphy is revealed:

Section of Clay Pit at Booneville.

	Feet
4. Sandy loam (Columbia)	2–3
3. Reddish clay	3–5
2. Bluish clay	4
1. White chalk containing shells	...

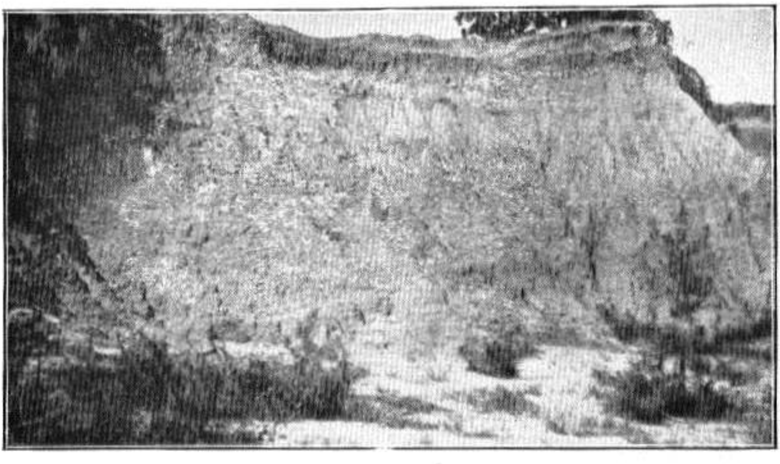
A little higher up the clay has a greater thickness, as the record of Mr. H. T. Turkett's well seems to indicate.

Turkett Well Record, Booneville.

	Feet
1. Yellow and blue clay	20
2. Blue limestone	20
3. Water-bearing sand	5

PLATE XXXVII

A. RESISTANT LAYER IN THE COLUMBIA LOAM, BRANDON.



B. LAFAYETTE SANDS, BRANDON THE RED SAND OF THE OUTCROP WEATHERED WHITE IN THE FLAT BELOW.

Clay No. 2 of the pit section has the maximum shrinkage when hard burned, and No. 4 the minimum shrinkage. The brick shrink about ½ inch in length and ¼ inch in width. A mixture of these clays is used in the manufacture of brick and tile. In drying the brick, care must be exercised to prevent the currents of air from striking the brick too soon after they are brought from the machine. Too rapid drying at first causes cracking and checking. Because of the presence of lime and ironstone concretions in some parts of these clays, care must also be exercised in burning to prevent fusion in some parts of the kiln before the brick in the other parts have reached the proper hardness. The lime acts as a flux to melt the iron. This action runs the brick together in a slaggy mass. The ends of the eye-brick are usually glazed by this reducing action of the lime. No granulator, disintegrator or pug mill is used in preparing and tempering the clay. It is molded in a stiff-mud side-cut machine. The brick and tile are burned in rectangular up-draft kilns of the clamp type. The company also manufactures some drain tile each year.

Thrasher.—At Thrasher, the Thrasher Brick Manufacturing Company opened a yard for the manufacture of brick in 1906. The clay used is a surface clay, probably of Columbia age. Its prevailing color is yellow. The brick are molded in a stiff-mud machine of the plunger type. They are burned in rectangular up-draft kilns.

RANKIN COUNTY.

GEOLOGY.

The subsurface of Rankin County is occupied by Tertiary strata belonging to the Jackson, Vicksburg and Grand Gulf groups. The surficial formations are the Lafayette and the Columbia.

CLAY INDUSTRY.

Brandon.—The Columbia has been used at Brandon in the manufacture of brick by the soft-mud process. One plant was located southeast of town and another across from the Alabama and Vicksburg station, northeast of town. Neither of these plants is in operation at present.

On the slope of the hill above the Alabama and Vicksburg station there is an exposure of Lafayette clay which has the following composition:

TABLE 92.

ANALYSIS OF COLUMBIA CLAY, BRANDON.

	No. 74
Moisture (H_2O)	4.89
Volatile matter (CO_2 etc.)	4.86
Silicon dioxide (SiO_2)	75.16
Iron oxide (Fe_2O_3)	5.77
Aluminum oxide (Al_2O_3)	7.75
Calcium oxide (CaO)	.62
Magnesium oxide (MgO)	.87
Sulphur trioxide (SO_3)	.00
Total	99.92

RATIONAL ANALYSIS.

Clay substance	19.60
Free silica	66.05
Impurities	7.26

At the foot of the hill, east of the station at Brandon, there is an outcrop of white Vicksburg limestone. South of the station at a little higher level is a marl which is highly fossiliferous. The section exposed is as follows:

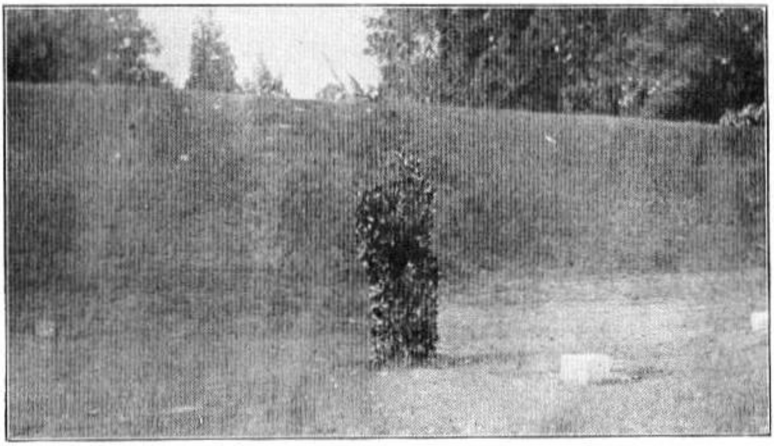
Section South of the Railroad Station, Brandon.

	Feet
4. Brownish loam	5
3. Red to purple clay	4
2. Yellow clay	1
1. Marl containing shells	6

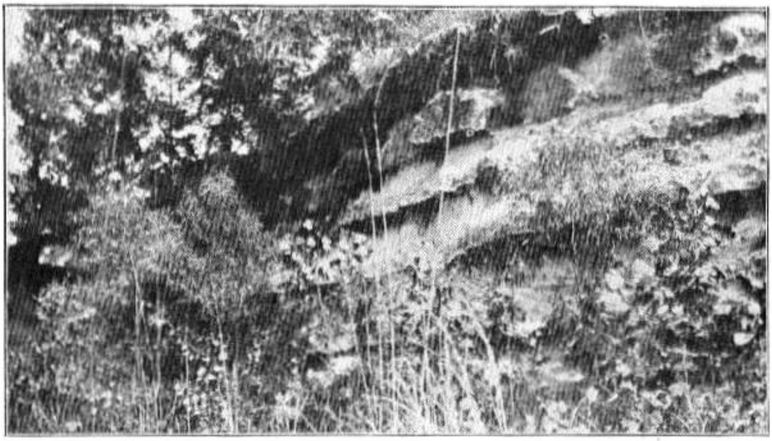
Layers 2 and 3 are residual clays formed by the decomposition of the marl.

In an abandoned railroad cut, at the top of the divide upon which Brandon is located, there is an outcrop of Lafayette sand capped by a layer of light brown loam. The Lafayette, in places, weathers to a white sand. The grains of sand are coarse and mostly fragments of transparent quartz crystals. Some of the grains are opaque white. About 25 feet of this sand is exposed. Farther west, the sand has partings of white clay at its base. Above the red sand there is a foot or two of lighter colored transition loam, then about one foot of hard, indurated resistant loam. So indurated is the layer that on an exposed surface it projects from the face of the exposure, and when

PLATE XXXVIII.



A. TERRACE IN THE LOESS AT THE NATIONAL CEMETERY, VICKSBURG.



B. VICKSBURG LIMESTONE, NEAR BRANDON.

broken up forms a sort of gravel. In places it serves as a sort of capping to protect the softer underlying rocks and thus produces a variety of small topographic forms. Above the indurated layer there is an exposure of about 4 feet of brown loam covered by a foot or more of soil. A sample of clay from the indurated portion has the following chemical composition:

TABLE 93.

ANALYSIS OF COLUMBIA CLAY, BRANDON.

	No. 75
Moisture (H_2O)	1.56
Volatile matter (CO_2 etc.)	2.65
Silicon dioxide (SiO_2)	82.32
Iron oxide (Fe_2O_3)	5.77
Aluminum oxide (Al_2O_3)	5.17
Calcium oxide (CaO)	.50
Magnesium oxide (MgO)	.91
Sulphur trioxide (SO_3)	.09
Total	98.97

RATIONAL ANALYSIS.

Clay substance	13.08
Free silica	76.25
Impurities	7.27

The cementing substance in the hard layer mentioned above is undoubtedly silica. The amount of iron and of calcium carbonate does not seem adequate to form such a degree of induration.

Rankin State Farm.—In an attempt to find a clay suitable for the manufacture of brick on the State farm in Rankin County the writer collected a number of samples. A chemical analysis of one of these samples was made with the following results:

TABLE 94.

ANALYSIS OF CLAY, RANKIN COUNTY STATE FARM.

	No. 71
Moisture (H_2O)	.81
Volatile matter (CO_2 etc.)	9.20
Silicon dioxide (SiO_2)	81.72
Iron oxide (Fe_2O_3)	4.81
Aluminum oxide (Al_2O_3)	.86
Calcium oxide (CaO)	.62
Magnesium oxide (MgO)	.89
Sulphur trioxide (SO_3)	.36
Total	99.27

RATIONAL ANALYSIS.

Clay substance	2.17
Free silica	80.71
Impurities	6.58

The absorption of clay No. 71 is 14.94 per cent. It contained such a small amount of clay substance that it was deficient in bonding power. It is about four-fifths sand and contains more than 6 per cent of fluxing impurities.

SCOTT COUNTY.

GEOLOGY.

The substrata of Scott County belong to the Claiborne, Jackson and Vicksburg. The Lafayette and Columbia form the surficial formations. There are also some residual clays formed from the Jackson marls.

CLAY INDUSTRY.

Forest.—At Forest, a residual Jackson clay outcrops in a small ravine in the western part of the town. The analysis of this clay is given in No. 113, below:

TABLE 95.

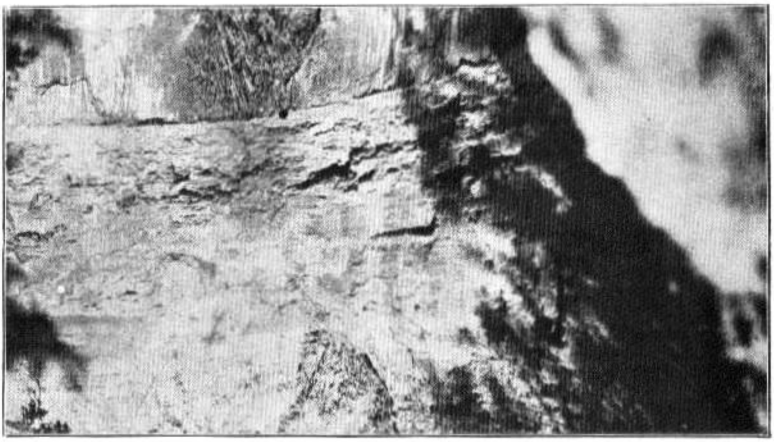
ANALYSES OF CLAYS, FOREST

	No. 113	*No.* 112
Moisture (H_2O)	5.05	1.80
Volatile matter (CO_2 etc.)	6.41	2.48
Silicon dioxide (SiO_2)	69.01	86.38
Iron oxide (Fe_2O_3)	8.02	2.82
Aluminum oxide (Al_2O_3)	5.60	1.23
Calcium oxide (CaO)	2.50	4.17
Magnesium oxide (MgO)	.48	.27
Sulphur trioxide (SO_3)	.51	.02
Total	98.58	99.17

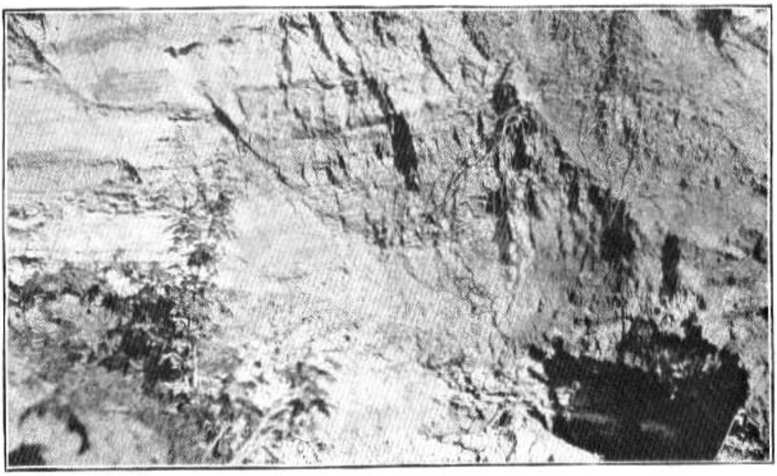
RATIONAL ANALYSIS.

	No. 113	*No.* 112
Clay substance	20.29	3.11
Free silica	56.74	84.50
Impurities	10.19	7.28

A sample of clay taken from a railroad cut near the station belongs to a surface loam. The deposit contains some pebbles at the base and the clay has some small gravels. It is probably Lafayette or Columbia. The composition of a sample is given in No. 112 of the above table. The burned brickettes have an absorption of 9.02 per cent.



A. LIGNITIC STRATUM IN THE JACKSON SANDS, MORTON.



B. LOCAL FAULT IN THE JACKSON STRATA, MORTON.

Morton.—In the southern part of the town of Morton there is an outcrop of Jackson which has the following stratigraphy (see Plate XXXIX, *A*):

Section of the Jackson, Morton.

	Feet
3. Grayish clay in thin layers	5
2. Lignite and lignitic clay	6
1. White sand, cross bedded with clay partings	15

In another outcrop southeast of the above mentioned point, there are exposed about 6 feet of grayish sticky clay which has resting upon it an alternating bed of clay and sand with a thickness of 20 feet. At one place in this outcrop a fault having a throw of 4 feet is visible. (See Plate XXXIX, *B*.) The grayish clay has the following chemical composition:

TABLE 96.

ANALYSIS OF JACKSON CLAY, MORTON.

	No. 90
Moisture (H_2O)	7.35
Volatile matter (CO_2 etc.)	10.12
Silicon dioxide (SiO_2)	61.82
Iron oxide (Fe_2O_3)	2.80
Aluminum oxide (Al_2O_3)	12.28
Calcium oxide (CaO)	.82
Magnesium oxide (MgO)	.54
Sulphur trioxide (SO_3)	.04
Total	95.77

RATIONAL ANALYSIS.

Clay substance	31.06
Free silica	43.04
Impurities	4.20

Clay No. 90 requires 22 per cent of water for plasticity; has a tensile strength, raw, of 81 pounds per square inch; burned, 131 pounds per square inch; has a total shrinkage of 10 per cent; and has an absorption of 11.11 per cent. Mixed with 10 per cent coal it has a total shrinkage of 7 per cent; has a tensile strength, raw, of 100 pounds; and has a tensile strength, burned, of 233 pounds per square inch. When mixed with 10 per cent cinders its total shrinkage is 7 per cent; its tensile strength, raw, is 100 pounds, and burned is 235 pounds per square inch.

SUNFLOWER COUNTY.

GEOLOGY.

Sunflower County lies within the Yazoo basin and its entire surface formation is alluvium. Sandy loams and stiff black clays form the surface. Underlying the alluvial deposit are the clays, sands and sandstones of the Claiborne and Wilcox.

CLAY INDUSTRY.

Indianola.—The alluvial clays are being used at Indianola in the manufacture of brick. Two plants are in operation at this point; both of them use the dry-press process of manufacture.

In the pit used by the Indianola Brick and Tile Company the following strata are exposed:

Section of Clay Pit, Indianola.

	Feet
3. Yellowish loam	3
2. Dark colored clay (buckshot)	2
1. Yellowish clay	6

A sample of No. 1 was taken for analysis with the following result:

TABLE 97.

ANALYSIS OF ALLUVIAL CLAY INDIANOLA.

	No. 54
Moisture (H_2O)	5.00
Volatile matter (CO_2 etc.)	7.57
Silicon dioxide (SiO_2)	60.00
Iron oxide (Fe_2O_3)	4.62
Aluminum oxide (Al_2O_3)	20.00.
Calcium oxide (CaO)	.80
Magnesium oxide (MgO)	.47
Sulphur trioxide (SO_3)	.85
Total	99.31

RATIONAL ANALYSIS.

Clay substance	50.60
Free silica	36.48
Impurities	6.74

Clay No. 54 requires 20 per cent of water to render it plastic. It loses 13 per cent in weight in burning. In the raw state its tensile strength is 262 pounds. The burned brickettes have a strength of

390 pounds. It burns to a red color but fuses at a moderately low temperature. Great care must be exercised in drying and burning to prevent cracking and swelling. The stratum is not used alone but is mixed with the overlying leaner clay, and more satisfactory results are obtained. The effect of the top clay is to facilitate drying and lessen shrinkage. When burned hard the center of the bricks are steel blue in color. The hard-burned bricks have a water absorption of 9.3 per cent.

The Sunflower Brick Manufacturing Company also operates a plant at Indianola. The plant is located on the line of the Southern Railway, west of town. The pit as far as opened at the time of the visit of the writer exhibited the following:

Section of Clay Pit, Indianola.

	Feet
2. Light grayish, loamy clay	3
1. Dark colored clay	6

Samples of clay were taken from both of these layers. The analyses are given below. Analysis No. 52 was made from layer No. 1 and No. 53 from layer No. 2.

TABLE 98.

ANALYSES OF BRICK CLAYS, INDIANOLA.

	No. 52	*No. 53*
Moisture (H_2O)	7.27	2.15
Volatile matter (CO_2 etc.)	2.40	4.85
Silicon dioxide (SiO_2)	71.17	71.67
Iron oxide (Fe_2O_3)	6.04	7.90
Aluminum oxide (Al_2O_3)	10.06	8.10
Calcium oxide (CaO)	1.00	.90
Magnesium oxide (MgO)	1.16	.94
Sulphur trioxide (SO_3)	.48	.62
Total	99.58	97.13

RATIONAL ANALYSIS.

	No. 52	*No. 53*
Clay substance	25.47	20.49
Free silica	11.83	62.15
Impurities	8.68	10.36

Brickettes of clay No. 52 lose 14 per cent in weight in being burned. The clay becomes plastic when mixed with 22 per cent of water. It has a total shrinkage of 10 per cent. The tensile strength of the raw clay is 300 pounds.

Clay No. 53 is rendered plastic by the addition of 20 per cent of water. The air shrinkage is about 5 per cent. The tensile strength of the raw clay is 100 pounds. The burned brickettes have a strength of 300 pounds per square inch.

Moorhead.—A sample of alluvium clay of the plastic "buckshot" type was collected near the plant of the Moorhead Manufacturing Company at Moorhead. The clay is bluish black in color and of very fine grain. The amount of water required to render it plastic is 25.89 per cent. In the raw state the clay has a tensile strength of 142 pounds. When burned hard it has a strength of 840 pounds. The total amount of shrinkage is 15 per cent. The chemical composition is given below:

TABLE 99.

ANALYSIS OF BUCKSHOT CLAY, MOORHEAD.

	No. 115
Moisture (H_2O)	7.20
Volatile matter (CO_2 etc.)	8.00
Silicon dioxide (SiO_2)	58.16
Iron oxide (Fe_2O_3)	4.95
Aluminum oxide (Al_2O_3)	17.25
Calcium oxide (CaO)	3.22
Magnesium oxide (MgO)	.27
Sulphur trioxide (SO_3)	.27
Total	99.32

RATIONAL ANALYSIS.

Clay substance	43.64
Free silica	31.77
Impurities	8.71

TATE COUNTY.

GEOLOGY.

The entire subsurface of Tate County is the Wilcox (Lagrange) division of the Tertiary. The mantle-rock formations are the Lafayette, the Loess, the Columbia and the Yazoo alluvium. The last two are the sources of the brick material.

CLAY INDUSTRY.

Senatobia.—The brown loam clay is used at Senatobia in the manufacture of brick. T. B. Montgomery and Son operate a plant at this point. The plant was established in 1900. The clay is tempered in soak pits and molded in a soft-mud machine operated by horse power. The brick are placed upon pallets and racked in covered racks for drying. They are burned in up-draft kilns of the rectangular form. The local stratigraphy is disclosed by the well record at the plant:

Record of Montgomery Well.

	Thickness Feet	Depth Feet
4. Brown loam (Columbia).................	12	12
3. Gravel (brown and white chert, Lafayette)	3	15
2. Red sandy clay.........................	8	23
1. White sand, water-bearing...............	17	40

The brown loam and the underlying clay of the Columbia are well developed in Tate County. With the proper selection and mixing of the loam and clay a good quality of brick may be obtained.

TIPPAH COUNTY.

GEOLOGY.

The Ripley formation comprises the bed-rock of the eastern part of Tippah County, while the western part is underlain by the basal division of the Eocene. The mantle rock formations are the Lafayette sands and clays and the brown loam of the Columbia. The latter forms the chief source of brick clay under the present development.

CLAY INDUSTRY.

Ripley.—At Ripley the Ripley Brick Manufacturing Company uses a surface clay from the Columbia in the manufacture of brick. The stiff-mud, end-cut machine of the auger type is used. The brick are burned in rectangular up-draft kilns. From the clay pit and the well at the brick yard the following local stratigraphic conditions were determined:

Section of Clay Pit, Ripley.	Feet
5. Soil..	1
4. Loam...	2
3. Brownish clay with buckshot at bottom.............	10
2. Sand (water-bearing)............................	1
1. Limestone with shells...........................	2

All of the layers above No. 1 belong to the mantle rock. No. 1 belongs to the bed rock.

A sample of clay from No. 3 has the following chemical properties

TABLE 100.

ANALYSIS OF BRICK CLAY, RIPLEY.	*No.* 110
Moisture (H_2O)	2.85
Volatile matter (CO_2 etc.)	2.80
Silicon dioxide (SiO_2)	82.20
Iron oxide (Fe_2O_3)	4.62
Aluminum oxide (Al_2O_3)	6.24
Calcium oxide (CaO)	1.05
Magnesium oxide (MgO)	.90
Sulphur trioxide (SO_3)	.04
Total	100.20
RATIONAL ANALYSIS.	
Clay substance	15.78
Free silica	74.87
Impurities	6.61

The above mentioned clay requires 17 per cent of water to render it plastic. Its total shrinkage is 6 per cent. The tensile strength of the raw brickettes is 168 pounds per square inch. When soft burned the strength is 135 pounds per square inch. Air dried brick lose 2 per cent in weight in being dried at 100° F. and 5 per cent more in burning.

TUNICA COUNTY.

GEOLOGY.

Tunica County lies wholly within the Yazoo basin. Its surficial formation is the Post-Pleistocene alluvium. The bed rock formation probably belongs wholly to the Wilcox.

CLAY INDUSTRY.

Robinsonville.—The clays of the alluvial deposit are used at Robinsonville in the manufacture of brick and drain tile. The brick are molded in a machine of the stiff-mud type, and burned in a beehive kiln.

There are two principal types of the Yazoo alluvium in Tunica County. The sandy type, which is found near the streams, and the clayey interstream-area type. Because of the shifting of the streams or of temporary currents across the Yazoo basin during the building of the flood plain, both of these types may be found at the same place succeeding each other every few feet in a vertical section. These two types are mixed in the manufacture of brick and drain tile.

UNION COUNTY.

GEOLOGY.

The bed-rock formations of Union County are the Selma chalk and the Ripley in the eastern part, and the Wilcox in the western part. The mantle rock formations are the Lafayette and the Columbia. Pontotoc Ridge, which crosses the county from north to south about the central portion, exhibits the best development of the Lafayette. Clays from both the surficial formations are used in the manufacture of brick in this county.

CLAY INDUSTRY.

New Albany.—Two brick manufacturing plants are located at New Albany. The Butler Brick Manufacturing Company has a clay pit on the west side of a small ridge extending south of New Albany. The clay on the ridge is probably Lafayette, though the lower portion may be residual Ripley. The brick yard well pierced about 20 feet of this clay. The slopes of the Lafayette are covered with a mantle of brown loam, which increases in thickness toward the valley. The red-colored Lafayette clay is too sticky to be used in the soft-mud process of brick making. A sample of the Lafayette clay has the following chemical properties:

TABLE 101.

ANALYSIS OF LAFAYETTE CLAY, NEW ALBANY.

	No. 109
Moisture (H_2O)	2.27
Volatile matter (CO_2 etc.)	2.77
Silicon dioxide (SiO_2)	80.13
Iron oxide (Fe_2O_3)	4.62
Aluminum oxide (Al_2O_3)	9.00
Calcium oxide (CaO)	.25
Magnesium oxide (MgO)	.14
Sulphur trioxide (SO_3)	.09
Total	99.27

RATIONAL ANALYSIS.

Clay substance	22.77
Free silica	69.55
Impurities	5.10

The physical properties of clay No. 109 are as follows: It requires 17 per cent of water for plasticity. It has a total shrinkage of 5 per cent. Its tensile strength, raw, is 50 pounds per square inch.

The brown clay of the slope has been used by the above mentioned company in the manufacture of brick. The composition of this clay is given below:

TABLE 102.

ANALYSIS OF BRICK CLAY, NEW ALBANY.

	No. 108
Moisture (H_2O)	1.05
Volatile matter (CO_2 etc.)	2.85
Silicon dioxide (SiO_2)	85.24
Iron oxide (Fe_2O_3)	3.50
Aluminum oxide (Al_2O_3)	.71
Calcium oxide (CaO)	3.69
Magnesium oxide (MgO)	2.00
Sulphur trioxide (SO_3)	.86
Total	99.90

RATIONAL ANALYSIS.

Clay substance	1.79
Free silica	84.41
Impurities	10.05

Clay No. 108 requires 16 per cent of water for plasticity; has a shrinkage of 2 per cent, and has a tensile strength, raw, of 50 pounds.

A clay from a small valley is now being used at the Butler Brick Plant. The clay is prepared by the use of a disintegrator and granulator. It is tempered in a pug mill and molded in a soft-mud machine operated by steam power. The brick are burned in rectangular updraft kilns of the clamp type. A sample of clay from the valley has the composition given below:

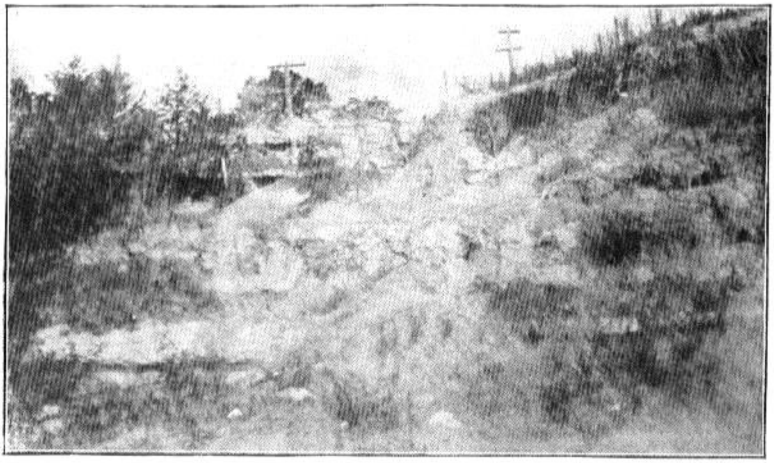
TABLE 103.

ANALYSIS OF BRICK CLAY, NEW ALBANY.

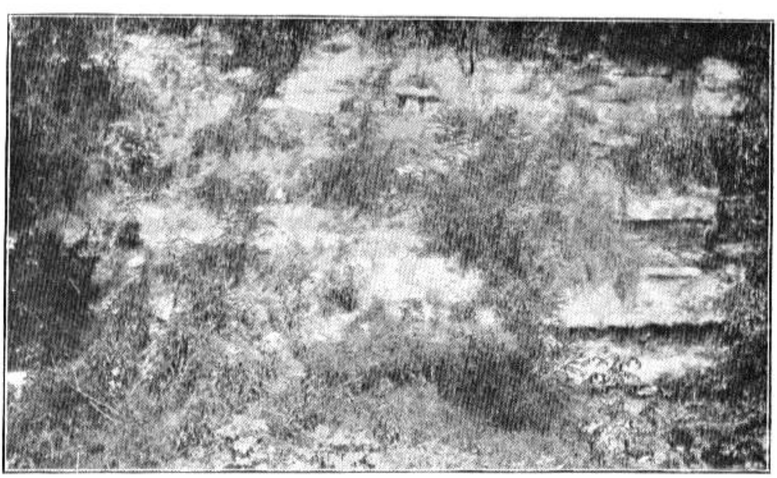
	No. 106
Moisture (H_2O)	1.10
Volatile matter (CO_2 etc.)	2.67
Silicon dioxide (SiO_2)	85.29
Iron oxide (Fe_2O_3)	3.44
Aluminum oxide (Al_2O_3)	4.44
Calcium oxide (CaO)	.44
Magnesium oxide (MgO)	.09
Sulphur trioxide (SO_3)	.17
Total	97.64

RATIONAL ANALYSIS.

Clay substance	11.23
Free silica	80.07
Impurities	4.14



A. VICKSBURG LIMESTONE, VICKSBURG, DISTANT VIEW.



B. VICKSBURG LIMESTONE, VICKSBURG, NEAR VIEW.

The physical properties of clay No. 106 are: Water required for plasticity, 16 per cent; air shrinkage, 1 per cent; fire shrinkage, 1 per cent or less; tensile strength, raw, 65 pounds per square inch.

The Union County Brick and Tile Company has a plant a short distance south of the Butler yard. The clay in its pit has a thickness of 10 feet. The upper part is a brown loam clay, and the lower portion is red Lafayette. The top clay cannot be used alone in the manufacture of dry-pressed brick. The best results are obtained by using the bottom clay. A sample of the red clay has the composition given below:

TABLE 104.

ANALYSIS OF LAFAYETTE CLAY, NEW ALBANY.

	No. 107
Moisture (H_2O)	2.55
Volatile matter (CO_2 etc.)	4.05
Silicon dioxide (SiO_2)	77.99
Iron oxide (Fe_2O_3)	6.25
Aluminum oxide (Al_2O_3)	8.37
Calcium oxide (CaO)	.06
Magnesium oxide (MgO)	.27
Sulphur trioxide (SO_3)	.51
Total	100.05

RATIONAL ANALYSIS.

Clay substance	21.17
Free silica	68.15
Impurities	7.09

Clay No. 107 has an absorption of 13.79 per cent; requires 18 per cent of water for plasticity; has a total shrinkage of 3½ per cent; has a tensile strength, raw, of 60 pounds per square inch, and burned of 50 pounds.

WARREN COUNTY.

GEOLOGY.

The bed rock formations of Warren County belong to the Vicksburg, Jackson and Grand Gulf stages of the Tertiary period. In the bluffs near the Mississippi and Yazoo Rivers in this county there are numerous exposures of Vicksburg limestone. Such outcrops are found both north and south of the city of Vicksburg. The road leading north from Vicksburg to the National Military Cemetery passes along the foot of the bluff, the lower portion of which is formed by an almost unbroken wall of Vicksburg limestone. (See Plate XLVII.) The limestone consists of 5 to 6 layers, which are interbedded with marl. The limestone beds vary in thickness from 1 to 6 feet. A dark laminated clay or marl is exposed in a creek bed about 20 feet below these limestones. At a point where the cemetery road approaches the nearest point to Finnie Lake, the outcrop of limestone is capped with 30 feet or more of shell marl. The shells are very abundant. The upper portion of the marl contains lens-like clay stones which are brown on weathered surfaces and purple on fresh fractures. The surfaces of these stones are generally channelled and irregular. The marl contains some ironstone concretions of irregular shape. The freshly exposed marl is bluish gray in color. Under the action of the weathering agents it changes first to dark red or purple and finally to yellow.

The upper part of the bluff is capped by 20 feet or more of Loess. In other places it is thicker. Resting upon the Loess at Vicksburg there is a brownish colored clay which is used in the manufacture of brick. This clay is probably a residual product resulting from the decomposition of the Loess.

CLAY INDUSTRY.

Vicksburg.—The J. D. Tanner Brick Manufacturing plant was established about 1880. The brick are manufactured by the soft-mud process, being molded by hand. The clay is tempered in a ring pit. The brick are burned in rectangular up-draft kilns.

The clay pit, which is located on a hill, has the following stratigraphy, the divisions not being very clearly defined:

Section at Tanner Brick Plant, Vicksburg.	Feet
4. Soil	1
3. Loamy clay, grading into 2	2
2. More plastic clay	4
1. Loess	2+

No. 1 has a thickness of 50 feet or more in some places. It lacks plasticity and is not used by itself in the manufacture of brick. The remainder of the section seems to be the residual product, resulting from the weathering of the Loess. While retaining some of its physical characters, it has lost much of its soluble matter. Especially has the amount of calcareous matter been greatly reduced. The lime con-

PLATE XLI.

EROSION IN BROWN LOAM AND LOESS, NATIONAL PARK, VICKSBURG.

cretions and the gastropod shells, so characteristic of the Loess, have disappeared. There is a decided gain in clay substances, consequently a gain in plasticity. The joint structure has been developed.

In the manufacture of soft-mud brick at the Tanner plant it is not possible to use the more plastic clay alone, so it is mixed with the Loess in the proportion of 1 foot of the latter to 5 feet of the former. Some of the physical properties of the clay are as follows: Its total shrinkage is only 3 per cent, practically all of which is air shrinkage. The raw clay has a tensile strength of 66 pounds per square inch. The burned brickettes have a tensile strength of 144 pounds per square inch. The addition of 23 per cent of water is necessary for plasticity. The loss of weight in passing from an air dried to a burned condition is 4 per cent. The burned brickettes absorb 12 per cent of water.

The Gregory Brick Manufacturing plant, established in 1906, is located in the southern part of Vicksburg. The clay used is taken from a pit on the side of a small depression near the plant. The clay changes from the surface downward from a sandy loam to a plastic joint clay. The Loess lies below the clay. It contains white lime concretions of irregular shapes, somewhat resembling potatoes with their protuberances. White gastropod shells are also abundant in the Loess. The clay is tempered in a ring pit and molded by hand. The brick are burned in rectangular up-draft kilns.

The Beck Brick Manufacturing plant is located on one of the Loess ridges in the southeastern part of Vicksburg. The plant was established in 1889. They use clay and loess in the proportion of 1 part of loess to 5 parts of clay. The treatment of the clay is similar to that of the other plants. It is tempered in the ring pit and molded by hand. After being dried in the open yard, the brick are burned in rectangular up-draft kilns.

The Garbish Brick Manufacturing Company operates a plant in the northern part of Vicksburg. The residual Loess clay is carted from the hill which rises above the low ground next to the river. The clay is mixed with the Loess in the proportion of 12 loads of clay to 3 loads of Loess.

The Thornton Press Brick Company operated a plant at Vicksburg until 1905, when the plant was burned. The residual Loess clay was used in the manufacture of dry-pressed brick.

WASHINGTON COUNTY.

GEOLOGY.

Washington County lies wholly within the Mississippi flood plain in the Yazoo delta. Its surface is occupied by the alluvium deposited during overflows from the river. The surficial material is of two types, viz., the sandy loams, so well represented on the borders of Deer Creek, and the dark "buckshot" clays, well developed in the Black Bayou region.

CLAY INDUSTRY.

Elizabeth.—A sample of clay collected from near the station at Elizabeth in Washington County has the following chemical composition:

TABLE 105.

ANALYSIS OF CLAY, ELIZABETH.	*No.* 58
Moisture (H_2O)	3.06
Volatile matter (CO_2 etc.)	3.94
Silicon dioxide (SiO_2)	69.22
Iron oxide (Fe_2O_3)	5.90
Aluminum oxide (Al_2O_3)	13.35
Calcium oxide (CaO)	2.75
Magnesium oxide (MgO)	1.15
Sulphur trioxide (SO_3)	.48
Total	99.85

RATIONAL ANALYSIS.	
Clay substance	33.77
Free silica	53.53
Impurities	10.28

The physical properties of the clay, so far as determined, are as follows: It has a total shrinkage of 5 per cent when burned to a hard state. It requires 19 per cent of water to render it plastic. The brickettes lose 10 per cent in weight in burning. They burn to a cherry red and are without cracks or checks. The tensile strength of the raw clay is 200 pounds per square inch. The burned brickettes have an absorption of 14 per cent. The clay is of fine grain and does not contain any gravel or large particles. A sandy type and a fat type are found within a short distance of each other, and are thus accessible for mixing. The railroad facilities at Elizabeth are excellent. This point is worthy of the investigation of those desiring to engage in the manufacture of brick and drain tile.

Greenville.—At Greenville the alluvial clay has been used in the manufacture of brick by the Greenville Dry Press Brick Company.

PLATE XLII.

TYPICAL LOESS TOPOGRAPHY, VICKSBURG.

The clay is of a dark color and belongs to the "buckshot" type. The brick are molded in a dry-press machine and burned in up-draft clamp kilns. A sample of clay from this pit has the following chemical composition:

TABLE 106.

ANALYSIS OF ALLUVIAL CLAY, GREENVILLE.

	No. 49
Moisture (H_2O)	4.21
Volatile matter (CO_2 etc.)	11.78
Silicon dioxide	58.82
Iron oxide (Fe_2O_3)	11.30
Aluminum oxide (Al_2O_3)	9.70
Calcium oxide	1.40
Magnesium oxide (MgO)	2.01
Sulphur trioxide (SO_3)	.50
Total	98.72

RATIONAL ANALYSIS.

Clay substance	24.54
Free silica	47.42
Impurities	15.21

The burned brickettes have an absorption of 11.11 per cent. The clay slacks slowly. When stirred wet it forms hard clods. The clay requires 19 per cent of water to render it plastic. It has a total shrinkage of 10 per cent. In the raw state its brickettes have a tensile strength of 190 pounds per square inch When burned hard they are red in color and have a tensile strength of 632 pounds. In the process of granulation the clay may be reduced to spherical grains, which in the molding process are not entirely obliterated. Under such conditions the soft-burned brick may crumble. When the brick are hard-burned the grains are destroyed. Great care must be exercised in burning the clay at high temperature to avoid swelling and cracking.

Hampton.—A sample of alluvial clay collected from near the station at Hampton belongs to the sandy loam type and has the following physical properties: The total shrinkage is about 3 per cent. Its tensile strength, raw, is 53 pounds, and when burned it has a strength of 116 pounds. It requires 19.1 per cent of water to render it plastic. The clay loses 26 per cent of its weight in drying and burning, 7 per cent being lost between the air-dried and the burnt states. This sample was taken about 1 foot below the surface. Another sample taken from a lower level has a total shrinkage of 4 per cent. Its loss of weight in drying and burning is 24 per cent. Its absorption is 14.81 per cent. In the raw state it has a tensile strength of 180 pounds per square inch, and when soft-burned its strength is only 110 pounds. In grain it is coarse, but does not contain any loose particles.

WEBSTER COUNTY.

GEOLOGY.

Webster County lies wholly within the borders of the Wilcox (Lagrange) division of the Tertiary. The formation consists of clays and unconsolidated sands with intercalated beds of lignite. Many good pottery clays occur in the formation. A small hand pottery at Cumberland manufactures a general line of stoneware. One of the clays from this formation is used at Maben in the manufacture of white brick. The surface formations of the county consist of the sands and clays of the Lafayette and the loams of the Columbia.

The analysis of the white clay used at Maben in the manufacture of white brick may be seen on page 212.

WINSTON COUNTY.

GEOLOGY.

Winston County lies mainly within the Wilcox-Eocene, though there is a small area of Tallahatta buhrstone in the southwestern corner. The surficial deposits are of Lafayette and Columbia age. The Wilcox (Lagrange) contains some good beds of white pottery clays. It also contains beds of lignite. The chemical composition of one of the white pottery clays from the J. A. M. Loyd pottery pit near Webster is given below:

TABLE 107.

ANALYSIS OF POTTERY CLAY NEAR WEBSTER.

	No. 68a
Moisture (H_2O)	.47
Volatile matter (CO_2 etc.)	9.24
Silicon dioxide (SiO_2)	59.82
Aluminum oxide (Al_2O_3)	27.19
Iron oxide (Fe_2O_3)	1.26
Calcium oxide (CaO)	.49
Magnesium oxide (MgO)	.37
Sulphur trioxide (SO_3)	.31
Total	99.15

RATIONAL ANALYSIS.

Clay base	68.90
Free silica	18.11
Fluxing impurities	2.12

CLAY INDUSTRY.

Louisville.—The surface clays are used at Louisville in the manufacture of brick by two companies. The Storer and Miller Company have a yard located north of town on the line of the Mobile, Jackson and Kansas City Railroad. The clay used is a red clay, probably of Lafayette age. The upper portion is sandy. There seems to be about 6 feet of residual clay with a red and white clay below. The clay at this point is prepared in a disintegrator and granulator, and tempered in a pug mill. It is molded in an end-cut stiff-mud machine. The brick are dried in covered racks and burned in up-draft kilns.

Langley Brothers operate a brick plant south of Louisville. The clay used is a surface loam which is mixed with a white plastic clay underlying the loam. The general stratigraphy of the locality is revealed in a well near the pit.

Section of Well at Langley Brothers Brick Plant, Louisville.

	Feet
3. Surface loam (yellow)	6
2. Red and white clay and sand	15
1. Blue sandy clay with lignite	4

YALOBUSHA COUNTY.

GEOLOGY.

The Wilcox (Lagrange) formation forms the subsurface of Yalobusha County. The surficial deposits are Lafayette and Columbia. The brown loam of the latter is the principal clay used in the manufacture of brick in this county.

CLAY INDUSTRY.

Water Valley.—At Water Valley the clay of the surface formations is used in the manufacture of brick by the Norris Brick Manufacturing Company. The plant was established in 1904. The brick are molded in a stiff-mud machine of the plunger type. They are dried in open air sheds and burned in rectangular up-draft kilns. The brick are sometimes dried in the sun without checking. The clay in the pit is of two kinds, a red clay at the bottom of the pit, probably Lafayette, and a brown clay overlying the red. The red clay cannot be used alone as it is too plastic. It may be used when mixed with the more non-plastic brown loam lying above.

YAZOO COUNTY.

GEOLOGY.

The chief bed rock formation of Yazoo County belongs to the Jackson division of the Eocene. It consists of clays, marls, sands and impure limestones, usually very fossiliferous. The bed rock is largely concealed by mantle rock belonging to the Pliocene, Pleistocene and Post-Pleistocene epochs. To the Pliocene may be assigned a series of cross-bedded sands, gravels and clays constituting the Lafayette formation. Both laterally and vertically the constituent materials of the formation vary greatly and pure beds of sand may be succeeded by pure beds of gravel and clay or by mixtures of the three. The colors are predominantly red, orange and yellow. The thickness of the formation rarely exceeds 50 feet. The Pleistocene is represented by the Loess and possibly by the Natchez formation, though the latter has not been definitely differentiated from the Lafayette in Yazoo County. The Loess is a very fine silt which in the process of weathering produces a surface loam with a clay substratum. The Columbia loam rests upon the Loess and, wherever the true Loess is absent, upon older formations. The flood plain of the Mississippi and the Yazoo Rivers in this county, called the Yazoo delta, is covered with alluvial material of Post-Pleistocene age.

There are two types of the alluvial material, a sandy loam and a plastic clay. The loam is generally light in color and of greater weight and is found near the streams. The clay is dark, light in weight and of finer grain and found in the interstream areas.

Topographically Yazoo County may be divided into the plain portion, that part included in the Yazoo Delta, and the hill portion, that section of the county lying east of the Yazoo River.

The surface of the county rises by means of an abrupt escarpment from the flood plain to the hill country. The flood plain area forms an exceeding level plain which lies about 100 feet above sea level.

The escarpment rises to a height of 250 to 300 feet above this plain. The surface descends from the escarpment toward the valley of Black River.

The river front of the escarpment presents a crenulated margin produced by small streams which have cut V-shaped valleys in its front. The position of the larger streams is marked by valleys with small flood plains which merge into the larger plain. The principal brick materials of the county are found in the residual clay of the Loess, and the clays of the delta, which may also be used for road ballast. Doubtless there are also deposits of the Lafayette and some residual clays of the Jackson which could be used in the manufacture of brick.

CLAY INDUSTRY.

Yazoo City.—A residual clay overlying the Loess at Yazoo City is used by the Montgomery Land Company in the manufacture of dry-pressed brick. The Loess assists in forming the bluffs along the border of the flood plain east of Yazoo City. These bluffs are mantled by residual clay, which is thin on the crest of the hills and becomes thicker in the depressions. On the steeper slopes it rarely ever reaches a thickness of 3 feet. In the depressions, however, a thickness of 8 feet is not uncommon. The clay substance usually increases toward the bottom of the pit. The Loess beneath is noticeably non-plastic as compared with the clay. The Jackson strata are revealed in outcrops near the base of the hills. The weathered surfaces of the exposures exhibit a gray joint-like clay containing shells. The clay is very plastic and seems to be free from sand. The Lafayette gravels rest upon the Jackson marls. The Lafayette covers the Jackson to the depth of 10 to 40 feet.

The chemical composition of the surface brick clay is given in the analysis below:

TABLE 108.

ANALYSIS OF SURFACE BRICK CLAY, YAZOO CITY.	*No.* 60
Moisture (H_2O)	2.37
Volatile matter (CO_2 etc.)	4.37
Silicon dioxide (SiO_2)	72.65
Iron oxide (Fe_2O_3)	5.81
Aluminum oxide (Al_2O_3)	11.25
Calcium oxide (CaO)	1.12
Magnesium oxide (MgO)	1.62
Sulphur trioxide (SO_3)	.30
Total	99.49

RATIONAL ANALYSIS.

Clay substance	28.46
Free silica	59.42
Impurities	8.85

The above mentioned clay has a tensile strength of 85 pounds per square inch in the raw state, and 175 pounds per square inch in the soft-burned condition. Its total shrinkage is 4 per cent of which 3 per cent is air shrinkage. It requires 18 per cent of water to render it plastic. The soft-burned brickettes absorb 15.25 per cent of water.

TABLE 109.

DIRECTORY OF MISSISSIPPI CLAY WORKERS.

Name of Firm	*Town*	*County*	*Product*
1. Austin Brick Co	Pontotoc	Pontotoc	Brick
2. Bacon Brick Manufacturing Co	Greenwood	Leflore	"
3. Baldwyn Brick & Tile Co	Baldwyn	Lee	"
4. Bay St. Louis Brick Co	Bay St. Louis	Hancock	"
5. Beck Brick Co	Vicksburg	Warren	"
6. Bledsoe Brick & Tile Co	Grenada	Grenada	"
7. Bonita Brick Co	Meridian	Lauderdale	"
8. Booneville Brick & Tile Co	Booneville	Prentiss	Brick and tile
9. Brown Brick Co	Crenshaw	Panola	Brick
10. Brookhaven Pressed Brick Co	Brookhaven	Lincoln	"
11. Bushman & McGinnis	Hattiesburg	Perry	"
12. Butler Brick Co	New Albany	Union	"
13. Bullard Brick Co	Jackson	Hinds	"
14. Buchanan Brick Co	Sardis	Panola	"
15. Camp Brick Co	Amory	Monroe	"
16. Carl Brick Co	Grenada	Grenada	"
17. Cassiby Brick Co	Gulfport	Harrison	"
18. Centerville Brick Co	Centerville	Wilkinson	"
19. Charleston Improvement Co	Charleston	Tallahatchie	"
20. Clarksdale Brick & Tile Co	Clarksdale	Coahoma	Brick and tile
21. Clermont Brick & Tile Co	Biloxi	Harrison	Brick
22. Cline Brick Co	Macon	Noxubee	"
23. Columbus Brick Co	Columbus	Lowndes	"
24. Concord Brick Co	Natchez	Adams	"
25. Corinth Brick Co	Corinth	Alcorn	"
26. Cowgill Drain Tile Co	Minter City	Leflore	Drain tile
27. Edwards Brick Co	Edwards	Hinds	Brick
28. Erby Brick Co	Holly Springs	Marshall	"
29. Furtick Brick Co	Rienzi	Alcorn	"
30. Fernwood Lumber Co	Fernwood	Pike	"
31. Garbish Brick Co	Vicksburg	Warren	"
32. Graham Brick Co	Lumberton	Lamar	"
33. Greenville Brick Co	Greenville	Washington	"
34. Gregory Brick Co	Vicksburg	Warren	"
35. Gulo Brick Co	Holcomb	Grenada	"
36. Hancock Brick Co	Newton	Newton	"
37. Hawkins & Hodges	Okolona	Chickasaw	"
38. Hazlehurst Brick Co	Hazlehurst	Copiah	"
39. Howard Brick Co	Starkville	Oktibbeha	"
40. Imperial Brick Co	Biloxi	Harrison	"
41. Indianola Brick & Tile Co	Indianola	Sunflower	"
42. Jesty Brick & Lumber Co	Winona	Montgomery	"

TABLE 109—Continued.

DIRECTORY OF MISSISSIPPI CLAY WORKERS—CONTINUED.

Name of Firm	*Town*	*County*	*Product*
43. Landon Brick & Tile Co	Landon	Harrison	"
44. Langley Brick Co	Louisville	Winston	"
45. Laurel Brick & Tile Co	Laurel	Jones	"
46. Leakesville Brick Co	Leakesville	Greene	"
47. Love Wagon Co	Durant	Holmes	"
48. Lowery & Berry Brick Co	Blue Mountain	Tippah	"
49. Maben Brick Co	Maben	Oktibbeha	"
50. Magnolia Brick Co	Magnolia	Pike	"
51. Montgomery Brick Co	Senatobia	Tate	"
52. Montgomery Land Co	Yazoo	Yazoo	"
53. Mt. Olive Brick Co	Mt. Olive	Covington	"
54. Natchez Brick Co	Natchez	Adams	"
55. Nettleton Manufacturing Co	Nettleton	Lee	"
56. New Houlka Brick Co	New Houlka	Chickasaw	"
57. Norris Brick Manufacturing Co	Water Valley	Yalobusha	"
58. Ocean Springs Brick Co	Ocean Springs	Jackson	"
59. Oxford Brick & Tile Co	Oxford	Lafayette	"
60. Pope Brick Manufacturing Co	Houston	Chickasaw	"
61. Quitman Brick Co	Quitman	Clarke	"
62. Rheinhart Brick & Tile Co	Clarksdale	Coahoma	Brick and tile
63. Ripley Brick Manufacturing Co	Ripley	Tippah	Brick
64. Riverside Brick Co	Hattiesburg	Perry	"
65. Robinsonville Brick & Tile Co	Robinsonville	Tunica	Brick and tile
66. Saltillo Brick Manufacturing Co	Saltillo	Lee	Brick
67. Smith Brick Co	Canton	Madison	"
68. Storer & Miller Brick Co	Kosciusko	Attala	"
69. Storer & Miller Brick Co	Louisville	Winston	"
70. Success Brick & Tile Co	Greenwood	Leflore	"
71. Summit Brick Co	Summit	Pike	"
72. Sunflower Brick Co	Indianola	Sunflower	"
73. Tanner Brick Co	Vicksburg	Warren	"
74. Taylor & Thomas Brick Co	Crystal Springs	Copiah	"
75. Taylor Brick Co	Jackson	Hinds	"
76. Thrasher Brick Co	Thrasher	Prentiss	"
77. Thornton Brick Co	Vicksburg	Warren	"
77a Tubbs Brick Co	Amory	Monroe	"
78. Union County Brick & Tile Co	New Albany	Union	"
79. Utica Brick Manufacturing Co	Utica	Hinds	"
80. Vaiden Brick & Tile Co	Vaiden	Carroll	"
81. Valley Brick & Tile Co	Lake View	De Soto	"
82. Vardaman Brick Co	Vardaman	Calhoun	"
83. Verona Brick & Tile Co	Verona	Lee	"
84. Weems Brick Co	Sun	Scott	"
85. Welch-Trotter Brick Co	West Point	Clay	"
86. West Point Brick Co	West Point	Clay	"
87. White & May Brick Co	McComb City	Pike	"
88. Woodville Brick Co	Woodville	Wilkinson	"
89 Cumberland Pottery	Cumberland	Webster	Stoneware
90. Holly Springs Stoneware Co	Holly Springs	Marshall	"
91. Allison Pottery Co	Holly Springs	Marshall	"
92. Davidson Pottery	Miston	Itawamba	"
93. Kennedy Pottery	Miston	Itawamba	"
94. Stewart Pottery	Perkinsville	Winston	"
95. Loyd Pottery	Webster	Winston	"
96. Lockhart Pottery Co	Lockhart	Lauderdale	"
97. Moorhead Manufacturing Co	Moorhead	Sunflower	Drain tile
98. Summerford Pottery	Miston	Itawamba	Stoneware

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