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THE

Clays and Clay Industries

OF

WISCONSIN.

BY

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WISCONSIN GEOLOGICAL AND NATURAL HISTORY SURVEY.

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INTRODUCTION.

The preparation of this report was commenced in June, 1899, since which time all the brick and drain tile factories in the state of which I have any knowledge, about one hundred and ninety in number, have been examined. The deposits of clay were carefully examined. The methods of manufacture and the economic conditions relating to the successful marketing of the products were given careful consideration.

By request most of the important brick manufacturers sent samples of clay to the Survey laboratory for examination. Chemical analyses have been made of nearly all the samples thus obtained, although a lack of time and equipment has necessitated the postponement of the physical and other tests until the present time. These tests are now being made and the results will be published in the second part of the report.

The information contained in this part of the report will be of interest and value to the general public as well as to the brickmaker, and is intended to stimulate the growing interest which is manifest in the development of the clay resources of Wisconsin. No attempt has been made to discuss in detail the methods of manufacturing the different clay wares, nor has any attempt been made to explain the difficult problems involved in the ceramic art. This volume is devoted largely to a summary of the present condition of the brick and drain tile industry in Wisconsin combined with a discussion of such elementary principles as are necessary to an intelligent understanding of the same.

Up to the present time the extent of the clay resources of Wisconsin and the nature of the clays which are being mined have been but vaguely comprehended by the citizens of the state. It is hoped that this report will assist the public to better understand the brick and drain tile industry of Wisconsin and appreciate, in part at least, the possibilities for its future development.

The investigation thus far conducted shows that the state contains unlimited quantities of clay suitable for the manufacture of common building brick, terra cotta, fire proofing, drain tile, and earthenware. There are also less extensive deposits of clay which give evidence of being admirably adapted to the manufacture of ornamental building brick. It is also believed that further examination will reveal limited deposits that can be advantageously utilized for the manufacture of paving brick and other vitrified wares. The most refractory clay or shale yet examined is only suitable for the manufacture of fire brick having a moderate fire-resisting capacity. Brick which are sufficiently refractory to serve the purpose for which three-fourths of the imported fire brick are used, can be manufactured in this state.

The very plastic white kaolin which occurs in Dunn and St. Croix Counties is admirably adapted to the manufacture of the highest grades of porcelain. At the present time it is being used almost exclusively in the manufacture of paper, for which purpose it is sold to the pulp and paper manufacturers of Minnesota, Wisconsin, and Michigan. It is thought that this kaolin might be successfully combined with the marl which occurs so abundantly in northeastern Wisconsin, for the manufacture of Portland cement.

Many of the low grade clays such as occur in the vicinity of the Great Lakes and in the Fox, Rock, and other river valleys are suitable for the manufacture of flower pots, cheap cuspidors, and other earthenware vessels which do not need to be vitrified.

With the decreased output of lumber in Wisconsin and the consequent rise in price, the people will eventually be forced to use brick, stone, or concrete as substitutes for wood in building constructions. The constant demand for a cheap and durable material will call into use enormous quantities of these materials. Clay must be used in the manufacture of brick and terra cotta in this state and will probably also be used in the manufacture of Portland cement. Everywhere the industrial and economic conditions point to a rapid development of the clay manufacturing industry.

The average annual output of the brick yards in Wisconsin during 1897, 1898, and 1899 was in the neighborhood of one hundred and fifty million common and pressed brick. During 1900 the output has been almost half again as great. The brick manufacturers within the state are constantly improving the methods of manufacture and within a few years the industry will be far in advance of what it is at the present time.

A large part of the previous work on the clays of Wisconsin is embodied in the four volumes of the Geology of Wisconsin published by the former Geological Survey of which Professor T. C. Chamberlin was director. Most of the discussions contained therein are devoted to the clays which occur in the vicinity of the Great Lakes. Reference is also made in these volumes to the residual clays, kaolins, and loess deposits. In the Transactions of the American Institute for Mining Engineers, volume VIII, pp. 502–506, 1879–80, and in the Transactions of the Wisconsin Academy of Sciences, Arts, and Letters, volume III, pp. 3–30, Professor R. D. Irving discusses in some detail the clay and kaolin deposits of the state. These further reports on the occurrence of clays in Wisconsin contain much important and valuable information and are worthy of the readers' careful perusal. For a general bibliography of clays the reader is referred to Bulletin No. 143, of the United States Geological Survey, compiled by Professor John C. Branner.

In the prosecution of this work I have been advised and assisted by the director of the Survey, Doctor E. A. Birge, and by Professor T. C. Chamberlin, who has aided in the determination of the age of the various clay deposits. I am greatly indebted to the brick makers throughout the state for the many courtesies which they have shown me and I desire in this place to express my thanks for their hearty co-operation. The chemical analyses which accompany this report were made by S. V. Peppel and W. S. Ferris, to both of whom I am greatly indebted for careful and painstaking work. I am indebted to the American Clay-Working Machinery company, Chisholm, Boyd and White, the Henry Martin Brick Machinery Mfg. Company, the Illinois Supply and Construction Company, and C. and A. Potts for the illustrations of clay working machinery used in this report. To all others who have in any way aided in the compilation and arrangement of this report I wish to express my hearty thanks.

E. R. BUCKLEY.

THE CLAYS OF WISCONSIN.

CHAPTER I.

ORIGIN OF CLAY.

All clay has its origin in the igneous or sedimentary rocks. The materials composing the sedimentary rocks were derived originally from the igneous rocks, so that these may be considered the ultimate source of all clay. The richness of a clay depends upon the source of the material of which it is composed and the conditions controlling deposition.

Classified with respect to their origin, all clays may be divided into two great classes: (1) Transported, (2) Residual. The first class includes all clay deposits formed by running water, ice or wind, and the second are such as result from the disintegration of the rock in place. In the first case disintegration and decomposition are followed by removal and redeposition, while in the second there is decomposition and disintegration of the rock in place, with only the removal of certain soluble salts by percolating water. In the first case the transported material or that which is carried away constitutes the clay, and in the second case that which remains constitutes the clay.

In the case of Sedimentary Clays the materials are derived from various sources being brought together by streams of water and assorted mechanically according to their degree of fineness and specific gravity. In the case of the residual clays the separation of the materials is largely chemical. Certain minerals are decomposed and the more soluble elements are taken into solution and carried away leaving a residual clay which often has a simpler chemical composition than that which is formed through sedimentation. On the other hand, the grains of the residual clay are unassorted and have a wider range in size than those of sedimentary origin. The grains of a residual clay have not suffered from attrition and are therefore much more irregular and angular in outline than the larger grains of a transported clay.

However, if the sources of material for the sedimentary deposits happen to be of the same character, mineralogically and chemically, the mechanical separation will have a tendency to further simplify the chemical and mineralogical composition.

The sedimentary deposits may be either soft or hard, on account of which they are spoken of as consolidated or unconsolidated sediments. The unconsolidated sediments are such as occur at the surface of the earth, as the latest deposits from rivers, lakes, glaciers, or the oceans. The consolidated sediments are known as shales or slates and occur mainly as a part of the older rock formations. The former do not need grinding but the latter must be reduced to a powder either by weathering or the use of machinery before they can be used.

The residual deposits may be either consolidated or unconsolidated. In fact one usually finds all gradations between the completely decomposed rock at the surface and that which is fresh and unaltered underneath. The decomposed rock at the surface may have lost all traces of its former structures. but if exploration is carried sufficiently deep the rock can usually be found in its unaltered state. That portion at the surface which is completely decomposed may be so soft that it can be used directly from the bank, but as the clay is exploited to a greater depth and it passes into partly decomposed rock, grinding will be necessary.

The composition of a residual or transported clay will depend in part upon the source of the mineral constituents out of which the clay is composed. The composition of a residual clay depends entirely upon the composition of the underlying rock. The composition of a transported clay depends upon the source of the detritus received by the river, lake or ocean in which it is deposited.

Wisconsin, for example, consists of a great central core of igneous rocks about which, on the south, west, and east, are wrapped concentric zones of limestone and sandstone. Much of the area is covered with glacial debris having a variable composition. However, if one knows the distribution of the rocks and glacial deposits, the direction of the flow of the rivers, the movement of the glaciers, and the former extent of the lake and river basins, he can make a fair general estimate of the composition of the clays in any part of the state. Consider, for example, the sedimentary clays of the Mississippi and Lake Michigan watersheds and it is easy to guess that within the north central crystalline area the clays will be low in calcium and magnesium and high in silica. One would likewise expect that the residual clays of this region would contain a moderately high percentage of alumina, iron and silica, and moderate amounts of potash and soda. The glacial clays that occur within the Lake Superior watershed would be surmised to be calcareous by persons who are familiar with the rocks occurring to the east and north.

The clays occurring south, east, and west of the Potsdam sandstone would be presumably high in calcium and magnesium, owing to the extensive limestone and dolomite formations which underlie them. The residual clays resulting from the decomposition of the limestone are naturally calcareous although not so much so as the clays formed by the mechanical attrition of the limestone. The heaviest beds of unaltered shale in Wisconsin occur between beds of limestone, on account of which it is more or less highly impregnated with calcium.

The knowledge that there occurs in north central Wisconsin extensive areas of feldspathic rocks which have been exposed to the weather since palaeozoic time naturally leads to the presumption that kaolin ought to occur in those sections where glaciation has not been sufficiently active to remove all the decomposed portions of the rocks. And even where removal has taken place, secondary concentration in lake beds or flood plains of rivers remain as possible sources of kaolin deposits.

A general familiarity with the rocks of the state and a knowledge of their distribution, combined with a familiarity with the river systems and the movements of the glaciers, furnish sufficient data upon which to base the above suppositions.

CHAPTER II.

COMPOSITION OF CLAY.

The term clay as ordinarily used has a very indefinite chemical, mineralogical, or physical significance, being usually applied to any mass of earth or shale which is used in the manufacture of terra cotta, stoneware, earthenware, brick, ornamental pottery, tile, sewer pipe, and other clay wares. So universal is the application of the term clay to all plastic or sticky masses of earth, that it is thought impracticable in a report of this nature to attempt to modify or even restrict its use. For this reason the term clay has been used in the most general sense and is made to include all earthy or stony substances which are or may be used in the manufacture of clay wares.

Clay in this sense consists of a great variety of minerals and has a very complex chemical composition. Among the common minerals of which clay is composed may be mentioned the following: Kaolinite, quartz, feldspar, limonite, hematite, magnetite, ilmenite, siderite, chlorite, epidote calcite, dolomite, rutile, mica, gypsum, alum, manganese, and carbon. Many of these minerals have a definite chemical composition, and when the proportion in which they are present is known one can determine with a fair degree of accuracy the chemical composition of the clay.

Kaolinite is a hydrous aluminum silicate, consisting of the elements silicon, oxygen, aluminum, and hydrogen, combined in the form of silica, alumina, and water. It has the chemical formula Al_2O_3, $2SiO_2$, $2H_2O$,$=H_4Al_2Si_2O_8$, which is interpreted as meaning that the mineral consists of 46.5 of silica ($Si O_2$), 39.5 alumina ($Al_2 O_3$), 14 water ($H_2 O$), —Dana. Kaolinite often occurs in massive deposits in which case it is generally known as kaolin. Kaolin or kaolinite is not known to occur anywhere as an original rock-forming mineral but at the surface of the earth it is always an alteration product of other minerals, commonly feldspar.

Kaolinite is a white or gray mineral substance with a hardness of from 1 to 2.6, having an easy cleavage in one direction and a pearly lustre. It is the base of all clays, the richness of which depends upon the percentage of kaolin present. A clay which has a very small percentage of kaolin is said to be lean, and one in which the percentage is high is said to be rich.

There are a number of hydrous aluminum silicates very similar to kaolinite in composition. There are amorphous and crystalline forms of kaolin, each of which has been given a different name. However, it has been thought impracticable and unnecessary in the following pages to distinguish between the several varieties of hydrous aluminum silicates and they are all spoken of as kaolin.

Kaolin contains 39.5 per cent. of alumina. Ordinarily none of the clays, except those that pass under the name of kaolin, exhibit by chemical analysis an alumina percentage of over 35 per cent. Clays used for commercial purposes, however, sometimes contain as little as 8 or 10 per cent of alumina. This indicates a relatively small proportion of kaolin in their composition.

Kaolin occurs both in what is known as the plastic and the non-plastic conditions. In the plastic condition it can be easily moulded into different shaped vessels which will retain their shape on drying. In the non-plastic condition it is necessary to mix the kaolin with another clay in order to contribute the necessary plasticity for moulding into the desired shapes.

In ordinary clays the kaolin occurs in the shape of plates or scales of different degrees of fineness. The plastic clays examined by the author occurred in very small plates or grains. The individuals were in many instances, less than 1/1000 of a millimeter in diameter.

Quartz is one of the common and almost constant associates of kaolin and is an important constituent of clay. It consists of silicon and oxygen and has the chemical formula, SiO_2. It occurs as an original constituent of most of the igneous rocks and is found abundantly in the rocks of the sedimentary series.

As a constituent of clay quartz occurs in grains of various shapes and sizes. It may occur in roundish grains of 1-50 millimeter or more in diameter or in irregular angular grains of smaller or greater size. Some clays contain as much as seventy-five or eighty per cent of quartz.

It is essential that every clay should have a greater or less percentage of quartz, since this mineral is one of the most important sources of silica.

Feldspar frequently occurs as a constituent of clays. It is an original constituent of most igneous rocks and owing to its variable chemical composition has been divided into several varieties. It is composed of either silica, alumina, and potash; silica, alumina, lime, and soda; or silica, alumina, and lime. The varieties which correspond in composition to the first two are most abundant and are known as orthoclase and oligoclase.

Orthoclase contributes mainly silica, alumina, and potash in the proportions of about 17.97 per cent. of alumina, 65.69 per cent. of silica, 13.99 per cent. of potash, and 2.35 per cent. of lime and soda. Oligoclase contributes 23.1 per cent. of alumina, 63.3 per cent. of silica, 4.4 per cent. of soda, and 4.2 per cent of lime.*

It is from the decomposition of the feldspars that kaolin is largely obtained. The potash, soda, lime and some silicia

*These compositions are from analyses given in Dana's System of Mineralogy.

are taken into solution and removed by the percolating waters, leaving the silicate of alumina or kaolin as a residual deposit. Feldspar occurs mainly in the igneous rocks and when found as a constituent of clay has probably been derived therefrom.

Limonite, hematite, magnetite, ilmenite, siderite and *pyrite*, are various forms in which iron occurs in clay deposits. The presence or absence of these minerals determines very often the purpose for which the clay can be used. A small percentage of iron will ordinarily impart a red, brown, or yellow color, destroying its usefulness for the manufacture of white ware. Iron also acts as a fluxing agent, increasing the fusibility of a clay.

The depth and shade of color imparted to the burned clay depends upon the form in which the iron is present, the amount, and the temperature at which the clay is burned.

Chlorite contains alumina, silicia, iron, and magnesium. It occurs in many of the schists and slates, and is sometimes found in the alluvial clays. It is always a secondary mineral, being formed by the decomposition of the minerals of the pyroxene and amphibole families.

Epidote is composed of alumina, silicia, iron and lime. Epidote is always a secondary mineral and occurs very largely in gneisses and schists. It results most frequently from the decomposition of feldspar and mica. It occurs in the shales and clays but is not often a very abundant constituent.

Calcite, or calcium carbonate, occurs in most of the clays and shales, and is a common constituent of both the eruptive and the sedimentary rocks. It is a secondary mineral and is not known to occur as an original constituent of the igneous rocks.

As a constituent of clay it increases the fusibility and neutralizes the color which would otherwise be imparted by any iron which may be present. Calcite is seldom a desirable constituent of clay. However, if present in small quantities it serves a valuable purpose in the manufacture of pottery or light colored terra cotta. If present in large quantities the calcite decreases the shrinkage through the formation of quick lime.

Dolomite is not as abundant a constituent of clay as calcite. It consists of magnesium and calcium in the form of a double carbonate. It is a secondary mineral resulting usually from the decomposition of the calcium-magnesium minerals of igneous rocks.

The effect which this mineral has on the burned clays is very similar to that of calcite. It neutralizes the color of the iron, increases the fusibility, and decreases the shrinkage when the ware is not vitrified.

Rutile is titanium oxide and occurs quite commonly in the shales and alluvial clays. It is an original constituent of many of the igneous rocks but also occurs as a secondary mineral in schists. It ordinarily occurs in very small amounts and is not considered very harmful.

Mica is a common constituent of both the igneous and sedimentary rocks, occurring both as a primary and secondary constituent. There are several quite distinct varieties, which contain varying proportions of alumina, silicia, potassium, magnesium, iron, fluorine, lithium, sodium and calcium. Mica is a common constituent of clays and as such increases its fusibility. It also increases the shrinkage and if present in considerable abundance modifies the color of the burned ware.

Gypsum is the sulphate of calcium and occurs mainly as a secondary mineral in shale. It has the same effect on the clay as calcite, neutralizing the iron, decreasing the shrinkage, when not vitrified, and increasing the fusibility.

Alum is one of the common soluble salts which occurs in shales and residual clays. It consists of alumina and potash in the form of the sulphate. It is objectionable in refractory clays, on account of increasing the fusibility and the production of sulphuric acid gas, whi[illegible]y cause blistering. It occurs mainly as a result of the decomposition of pyrite.

Manganese in the form of the oxide occurs in some clays. It is a very strong fluxing agent and when present in large quantities often produces an excellent slip clay. It is a very undesirable constituent of a clay used for the manufacture of refractory wares.

Organic matter is not ordinarily injurious to a clay owing to the fact that it is expelled on burning the ware. However, it often conceals in the raw clay the presence of iron which will impart a red color on burning. If the organic matter happens to occur in fragments of some size, it may burn out leaving the ware in a somewhat porous condition.

SUMMARY.

In general it will be observed that clay ordinarily has a complex chemical and mineralogical composition. The following outline shows the important elements entering into the composition of clay and the "clay" minerals of which they form a part or from which they are derived.

Aluminum	Kaolinite Feldspar Chlorite Epidote Mica Alum
Silicon	Kaolinite Quartz Feldspar Chlorite Epidote Mica
Calcium	Feldspar Epidote Calcite Dolomite Gypsum
Magnesium	Chlorite Dolomite Mica Epsom Salts

Sodium	Mica Feldspar Sulphate of Sodium
Potassium	Feldspar Mica Alum Sulphate of Potassium
Iron	Limonite Hematite Magnetite Siderite Pyrite Marcasite Mica Chlorite Epidote
Manganese	Manganese Oxide
Lithium	Mica
Titanium	Rutile
Carbon	Carbonates Lignite Woody fibres

CHAPTER III.

CLASSIFICATION OF CLAYS.

Frequent attempts have been made to classify clays on the basis of their origin, mineralogical and chemical compositions, physical properties, and usages. However, none of these classifications have apparently been satisfactory to both the scientist and the manufacturer.

Professor Edward Orton[1] has classified clays into two groups, viz.—high grade clays and low grade clays. These he further subdivides as follows:

High grade clays	1. Kaolin, 2. China Clay, 3. Porcelain Clay, 4. Fire Clay (hard), 5. Fire Clay (plastic), 6. Potters' Clay.
Low grade clays	1. Argillaceous Shale, 2. Ferruginous Shale, 3. Siliceous Clays, 4. Tile Clays, 5. Brick Clays, 6. Calcareous Clays.

H. A. Wheeler[2] contributes the following classification of clays:

1. White Ware: Kaolin, China-clay, Ball clay.
2. Refractory: Plastic fire-clay, flint clay, refractory shale.
3. Potters': Plastic clay and shale of moderate fusibility.

[1] Geological Survey of Ohio, Vol. VII, Part I, pp. 51–52, by Edward Orton.

[2] H. A. Wheeler, Clay Deposits, Geological Survey of Missouri, Vol. XI, p. 25, 1896.

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 ballast clay.
7. Slip: Clays of very easy fusibility.

George E. Ladd[3] has made the following classification considering clays from a geological standpoint:

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,
    - 1. Flood-plain,
    - 2. Delta.
- B. Meta-sedimentary,
- C. Residual,
- D. Unassorted.

Of the above classifications it is thought that the last is the most satisfactory although in certain respects I believe that even this should be modified. Kaolin, for example, is not always residual but frequently occurs as a sedimentary deposit. The author has included under the unassorted clays only those of glacial origin, although many of the indigenous clays are unassorted. Furthermore, kaolins are not the only indigenous clays, there being many other clays formed in situ or in the immediate place of their origin.

[3] George E. Ladd, Clays of Georgia, Geological Survey of Georgia, Bulletin No. 6 A, p. 10, 1898.

The following is a modification of the classification suggested by Dr. Ladd, and is offered as an addition to those with which the reader is already familiar:

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 the ice of the Glacial Epoch.
   - C. *Water.*
     1. Marine,
     2. Lacustrine,
     3. Stream.
   - D. *Wind.*
     Loess.

Any attempt to classify clays according to the uses to which they are put is almost sure to prove unsatisfactory. There is no other department of science that to my knowledge has attempted a classification on a similar basis. It would be very surprising to see a classification of building stones or ore deposits based upon the manufactured products. Likewise a classification of trees based on the uses to which they are put would be considered not only unscientific but irrational as well. We would then have "chair trees," "table trees," "shade trees," etc. The argument that each clay product requires a clay of a definite kind and composition is of course not true. For example, brick, drain tile, terra cotta, stone ware, etc., are made out of a mixture of clays no two of which have the same origin or composition.

It has always appeared to me that a scientific and rational classification of clays should be based on chemical, mineralogical, and physical properties. However, no one has thus far attempted to use these as a basis for formulating a classification. The person who undertakes such a task must have at hand chemical analyses, mineralogical determinations, and a knowledge of the size and shape of the grains of clays from many parts of the world. This can only be done after many years of close application to the study of the chemical, mineralogical, and physical aspects of clays. With a full appreciation of the difficulties involved in working out a scientific classification of clays, the author has submitted the above classification which is based primarily on position and secondarily on origin.

Many of the clays as above classified may be used for a variety of purposes but this fact ought not to weaken the classification. Further than this, very few of the clays are used solely for one purpose. They are usually mixed with one or more clays of a different nature, especially in the manufacture of the finer grades of pottery. A "stoneware" clay is often unsuitable for the manufacture of stoneware until mixed with another clay; and there is scarcely a piece of terra cotta that does not contain two or more clays in its composition.

Under the classification above given a residual clay from a granite or gneiss or a sedimentary clay may each be suitable for the manufacture of brick, stoneware, whiteware, ornamental pottery, or a variety of other uses. So with the residual clays from limestone, shale and the other rocks mentioned.

CHAPTER IV.

PROPERTIES AND BEHAVIOR OF CLAYS.

The following is a general classification of the properties of clay in the dry, wet, and burned condition, all of which should be known to the clay worker. The behavior of the clays in passing from the dry to the wet, from the wet to the dry, and from dry to the burned conditions are considered under this classification.

When dry:

- Color,
- Specific Gravity,
- Weight per cubic foot,
- Odor,
- Taste,
- Feeling,
- Hardness.

When wet:

- Absorption or porosity,
- Slacking,
- Shrinkage on drying,
- Plasticity,
- Feel.

When burned:

- Color,
- Shrinkage.
- Fusibility $\left\{ \begin{array}{l} \text{Incipient Vitrification} \\ \text{Complete Vitrification} \\ \text{Scoreaceous Vitrification} \end{array} \right.$

Color.— Kaolin, which is the essential constituent of all clays, is white. However, as previously explained, it seldom occurs alone, but is ordinarily mixed with an indefinite amount of iron oxide, pyrite, carbonaceous matter, mica, quartz, feldspar, manganous oxide, etc., all of which impart to the clay various shades of red, brown, yellow, blue, gray, green, purple, etc. The gray, blue, black, and purple shades are largely due to carbonaceous matter, while the red, yellow, and brown tints are largely attributable to iron oxide.

Clay containing a relatively small percentage of minerals other than kaolin are unsuitable for food adulterants, paper manufacture, and similar purposes for which kaolin is now used.

The black and blue colors due to carbonaceous matter are ordinarily destroyed when the clay is burned, while the color imparted by finely disseminated iron oxide is intensified upon burning. Most of the red, yellow, and brown effects seen in clay wares are imparted by iron oxide. However, the ordinary effect of iron oxide may be completely obscured in clays which contain a high percentage of calcium carbonate. The raw lacustrine clays of eastern Wisconsin have reddish and bluish tints but with the exception of that which occurs within a few feet of the surface the clay burns to a white or a cream color.

Mottled effects are produced either by mixing different clays or by adding the various oxides of the metals. The shade of red or brown produced by burning often depends upon the degree of heat and the oxidizing or reducing conditions under which the clay is burned.

Specific Gravity.— With reference to the specific gravity of clays as well as stones there has apparently been much confusion as to what is meant thereby.

Ladd [1] in his report on the clays of Georgia, remarks that the specific gravity ranges "from less than 1 to about 2.5,

[1] Ibid., p. 20.

pure kaolinite having a specific gravity of 2.60." Smock[1] in his report on the clay deposits of New Jersey, obtained specific gravities ranging from 1.528 to 2.170. Wheeler[2] in his report on Missouri clays, gives the specific gravity as ranging from 1.69 to 2.56.

The specific gravity of a clay may be obtained according to two very different conceptions. According to one of these conceptions the specific gravity will depend entirely upon the mineralogical composition being independent of the porosity of the clay. According to the other conception the pores are considered a part of the clay and the specific gravity is computed for the exterior volume.

The specific gravity of a clay, according to the first conception, depends entirely upon the mineralogical composition and is therefore unvarying. Grinding, pugging, pressing, or drying will not change the determination. The simplest method of obtaining the specific gravity, as thus conceived, is by the use of the specific gravity bottle.

Specific gravity determined according to the second conception depends both upon the mineralogical composition and the porosity. To what extent upon each, can, as a rule, only be approximately estimated from the chemical analysis. The specific gravity when obtained according to this method will always vary. If obtained for the clay as it occurs in the bank, the result will not be the same as that obtained for the same clay after slacking, pugging, pressing, or drying. Further, the specific gravity of the same clay will vary with the pressure applied and the amount of water used in moulding. If the specific gravity, determined according to this conception is to be of any value in a consideration of the fusibility of a clay, I believe that it should be obtained for the clay ware as it is placed in the kiln and not for the clay as it is sampled and examined in the laboratory. To obtain the specific gravity of a clay

[1] New Jersey Geological Survey, Report on the Clay Deposits, 1878, p. 284, by J. C. Smock.

[2] Ibid., pp. 90-91.

according to this conception, the sample should be thoroughly dried, coated with paraffine, and then weighed as for any ordinary solid.

It appears according to Wheeler,[1] that the specific gravity of a clay depends largely upon the overlying pressure to which it has been subjected, which is another way of saying that the specific gravity decreases with porosity. If this is true I believe that it would serve a better purpose to determine the porosity rather than the specific gravity, if the latter is to be obtained according to the method given above.

I am in sympathy with those who hold that the specific gravity of a clay is the specific gravity of the mineral particles of which the clay is composed. I believe that this should always be considered the true specific gravity of any substance composed of one or more minerals. If the porosity is desired it can be computed most readily by determining the specific gravity according to both methods. The specific gravity according to the second method subtracted from that by the first will give the difference in relative weights. The per cent. which this difference is of the first specific gravity gives the pore space.

Weight per cubic foot.—The weight per cubic foot of the clay as it occurs in the bank, after it has been pugged, and as it occurs in the green ware, after being moulded and dried will differ in each case. I do not know that very much importance can be attached to the weight of the clay, either as it occurs in the bank or after mixing and pugging. The weight per cubic foot of the clay as it occurs in the bank will furnish a basis for estimating the weight of clay moved, but other than this, has no commercial value. The weight of the clay also differs in various parts of the bank and for this reason a single determination would be of very little value. For this same reason the weight per cubic foot after mixing and pugg-

[1] Missouri Geological Survey, Clay Deposits, Vol. XI, pp. 90–91.

ing would be of very little importance. The weight after moulding and drying is of value only in estimating the weight sustained by the lower layers of ware in a kiln where stacking is the method of setting. The weight of a cubic foot of the dry ware can be obtained by multiplying the specific gravity of the "air encased" sample by 62.5 lbs. which is the weight of a cubic foot of water. However, for all practical purposes, the determination of the weight per cubic foot by this method is thought to be entirely unnecessary and of very little scientific value. If the weight is desired it can be best determined by actually weighing several pieces of the dry ware of known volume and averaging them.

Porosity.—The porosity of a clay, according to Wheeler,[1] has a direct bearing on its fusibility. If this be true, the determination ought to be made for the dry ware and not for the clay as it occurs in the bank. If the porosity should be determined for the clay as it occurs in the bank and the clay is afterwards ground, pugged and mixed with quartz or other clays,—as is usually the case,—the determination would have no significance whatever. The porosity of the ware as it enters the kiln might be very different from that of the raw clay and the bearing on its fusibility would vary accordingly. The porosity can be obtained by subtracting the apparent specific gravity from the specific gravity proper and reckoning the percentage which this difference is of the specific gravity proper. This last result will be the porosity.

In this connection I would suggest that students may be mistaken in attributing to the amount of pore space, those effects which are due to the size of the pores. The increased fusibility of a clay as far as pores are concerned, may be due primarily to the size of the pores and not to the porosity per volume. Wheeler says in his report on the Missouri clays that specific gravity, which

[1] Ibid.

is controlled very largely by the porosity of the clay, has an important bearing on its refractoriness. It seems to me that this is a very uncertain and difficult point to affirm or corroborate. A very fine grained clay may be as porous as one that is coarse grained, depending upon the heterogeneity of the particles. If two clays have the same composition, the specific gravities will be alike. However, the finer grained clay, according to Wheeler, will be most fusible. Nevertheless, when moulded and dried, it will have a tendency to be less porous than the one which consists of large sized particles. With these opposing conditions, it appears very probable that the whole matter is a question of size and shape of grain and not one of specific gravity and porosity. The size and shape of grain, of course, affect the specific gravity and porosity, but not always in the same manner.

Odor.—Most clays emit an earthy odor when breathed upon but seldom does one possess an odor by which it can be distinguished from others. Prospectors, however, frequently regard the intensity of the earthy odor as an indication of the "fat" or "lean" character of the clay. Judgment based upon this evidence is liable to be altogether erroneous, owing to the fact that some of the purest flint fire clays are reported to be almost devoid of smell.

Taste.—The presence of soluble substances, such as epsom salts, alum, sulphate of iron, etc., can frequently be detected by placing a small amount of clay in the mouth. By grinding the clay between the teeth, the relative size and abundance of the sand grains can be approximately determined. The tenacity with which the clay adheres to the tongue is an indication of the plasticity of the clay, and is frequently used to estimate this property.

Feel.—This test is used to estimate the fineness of the grains composing the clay and to determine the plasticity. If coarse sand or fine pebbles are mixed with the clay they can be detected by rubbing the clay between the fingers.

If the clay is tough and plastic it can be moulded into various shapes without breaking. If short and sandy it will crack and break when moulded.

When mixed with water, all plastic clays have a greasy feel which is most marked in the plastic kaolins. Many dry clays feel smooth when rubbed between the fingers, but only those which are rich in powdered kaolin or calcite have the peculiar greasy feel of talc. By continuous application one can become remarkably proficient in judging plasticity by merely feeling the dry sample.

Hardness.—The hardness of clay ranges from less than 1 to 3.5. Hardness in clay, as in stone, depends mainly on the coherence of the particles. Some of the arenaceous clays, in which the minerals themselves have a hardness approaching 7, have a hardness of only about 1, owing to their incoherent character. As the clays increase in richness and become more thoroughly compacted, the average hardness is lowered owing to the increased percentage of kaolin, and raised on account of the greater compactness and cohesion of the particles. The hardness of kaolin no matter how firmly compacted, cannot exceed that of the mineral kaolinite which is 1 to 2. The hardest clays are those in which there is an admixture of soft kaolin with other harder minerals such as quartz.

Hardness, which is the capacity which one substance has to scratch another, must not be confused with strength. Those clays which are rich in kaolin and calcite and most thoroughly compacted are probably the strongest.

The determinations of the hardness and strength of a clay have little or no value except as they may be used to determine the necessity for grinding and to estimate plasticity as hereafter described.

Slacking.—The property which a clay possesses on account of which it breaks down into a pulverent or flaky mass when soaked in water, is known as slacking. The lean, coarse grained clays, which do not occur in the form of a shale, usually break down into a granular or pulverulent mass. The fat, fine grained clays usually break down into a flaky or scaly mass. In case the clay is very fine grained and plastic the flakes will be large but very thin. These flakes are often so thin and light that they will float for an indefinite period on the surface of the water.

Ordinarily shale will not slack until it has been air dried. Then it frequently retains its lumpy character, only breaking down completely when pugged or ground in a wet pan.

The property of slacking is very important from a commercial standpoint. The mechanical separation of sand, iron oxide, and other mineral particles from kaolin depends for its successful operation upon the complete slacking of the clay. The weathering of clay by which soluble salts are removed, also depends for its success upon the slacking incident upon repeated wetting and drying.

Plasticity.—Plasticity is that property of a clay by which it can be formed into a multitude of shapes which will remain stiff and unchanged after moulding. The amount of water which it is necessary to mix with a clay in order that it will mould easily and yet be sufficiently stiff so that the ware will retain its shape, varies with the clay. A fine grained clay usually requires more water and is usually more plastic than one which is coarse. Very few minerals other than kaolin possess plasticity to any appreciable extent. Calcite, gypsum, talc, and several allied minerals are plastic but to a somewhat less degree than kaolin. The plasticity contributed to clays by calcite is well illustrated by the very plastic calcium clays of Wisconsin which are relatively low in aluminum and high in calcium and magnesium carbonate.

There is a class of shales having a high percentage of kaolin which are but slightly plastic. These, are mainly hard shales, known as flint or fire clays. These clays are always ground before being used and by this operation the plasticity is often materially increased.

The property of plasticity is of inestimable value and of primary importance. The cause of plasticity has been discussed by Wheeler,[1] Ladd,[2] Orton,[3] Cook,[4] and many other writers who have made a very careful study of the subject.

Although many different reasons have been advanced to account for the phenomenon there is as yet no consensus of opinion as to its cause. A few of the more important causes discussed by the writers in the reports above referred to are given below.

(1) One of the earliest theories advanced was based on the presence of water which was supposed to act as a lubricant. It is certain that there is very little plasticity if any without water, although the addition of water does not always produce plasticity.

(2) Another theory attributes plasticity to the presence of the mineral kaolin with which it is supposed to increase and decrease *pari passu*. This theory, however, does not answer for all cases. Some clays low in kaolin are very plastic, while others high in kaolin are almost devoid of plasticity.

(3) It has been further suggested that the impurities occurring in clay are a cause of plasticity. However, this likewise fails to account for all cases since certain highly plastic kaolins are very pure.

(4) The presence of vermicular or hooked shaped minerals such as have been described by Haworth and others, as occurring abundantly in the Missouri and other clays, has been suggested as a cause for plasticity, as well as a source

[1] H. A. Wheeler, Clay deposits of Missouri, Missouri Geological Survey Report, Vol. XI, pp. 97–103.

[2] Geo. E. Ladd, Clays of Georgia, Geological Survey of Georgia, Bulletin No. 6 A, pp. 29–34.

[3] Edw. Orton, Jr., Clays of Ohio, Geological Survey of Ohio, Vol. VII, Part 1, pp. 74–76.

[4] Geo. H. Cook, Clay Deposits of New Jersey, Geological Survey of New Jersey, 1878, pp. 286-289.

of the strength supplied to hold a clay in shape after being moulded. However, these minerals do not occur in all plastic clays and therefore they cannot be assigned as the sole cause for plasticity.

(5) The fineness of the individual grains is held as another cause of plasticity. However, it has been shown that many of the non-plastic flint clays are composed of grains which are smaller than those of the very plastic clays. If fineness of grain is the cause of plasticity, other minerals ought to develop this property in an equal degree with kaolin, when ground to the same degree of fineness. This is not the case.

(6) The theory that the shape of the individual grains is the cause of plasticity has met with the most general acceptance and in this connection Wheeler says, "The fine plate or minute scale theory seems to most satisfactorily explain the plasticity of clays and other lamellar minerals."

Respecting the theory of plasticity in general I would suggest the probability that eventually it will be found that no one of the above theories accounts entirely for the phenomenon but that several will be required to explain fully the facts. Further, the main cause of plasticity in one clay may not be a very important cause in others. All of the above reasons for plasticity may be necessary to fully explain the plasticity of all clays.

Shrinkage.— A clay that has been moulded in a wet condition gives off moisture upon drying, on account of which it decreases in bulk. This moisture is that which adheres as a film to the individual grains. It may have been a part of the clay as it occurred in the bank or added later in the process of tempering. This decrease in bulk is spoken of as the shrinkage of the clay on drying. The amount of shrinkage depends upon the fineness and shape of the grains and upon the quantity of moisture present.

The water in a clay occurs either in the interstitial spaces between the grains or as films separating the grains from one another. Where the grains are large and well rounded a greater part of the water is contained in the interstices, but where the individuals are small much of it occurs as films between the grains. It is the removal of these water films between the grains that is supposed to cause the shrinkage on air drying. Such being the case, it is easy to understand how the size of the grains controls very largely the shrinkage of a clay upon air drying.

A clay will shrink more when worked by the soft mud process than when worked by either the stiff mud or dry processes. Provided the composition and texture of two clays are the same, the shrinkage on air drying will depend upon the original water content and the amount of water added in mixing. The rapidity of air drying will not affect the amount of shrinkage although warping and cracking may result therefrom.

Shrinkage also usually results from the burning of a clay and is known as the *fire shrinkage.* This is due to the expulsion of chemically combined moisture, or water of crystallization, the consumption of carbonaceous matter, and the reduction of the porosity of the clay through vitrification. The maximum shrinkage is obtained at the point of complete vitrification, the mineral substance resulting therefrom being as a rule as dense as the individual, original minerals composing the clay.

Clay which has a high percentage of calcium or magnesium carbonate often swells when burned at a temperature below the point of vitrification. This is due to the conversion by heat of the carbonate of calcium or magnesium into the oxide and its subsequent conversion into the hydroxide upon exposure to the atmosphere. On the other hand a high percentage of quartz, owing to its permanent and refractory nature, will reduce materially the fire shrinkage of a clay.

The maximum amount of shrinkage due to burning will not vary for a given clay provided the heat is held sufficiently long to allow complete vitrification throughout the entire thickness of the ware. The prevalent idea that the amount of fire shrinkage will increase with the length of the burn is very misleading. The fire shrinkage varies with the degree and completeness of vitrification.

The practical importance of knowing the shrinkage of a given clay can be easily understood when one appreciates the necessity of furnishing the market with wares of a definite thickness, size, and weight. By making careful tests in the laboratory one can determine the size of the moulds which will be needed to produce tile or brick of a given thickness or size, with a given clay and a definite amount of water.

Fusibility.— Fusion occurs when a clay is raised to a temperature at which it passes from a solid into a liquid or viscous state. Before reaching this point the clay, owing to its heterogeneous mineralogical composition, passes through three stages known respectively as incipient, complete, and scoriaceous vitrification. The temperature at which any one of these stages is reached depends primarily upon the chemical and mineralogical composition of the clay, although it is influenced more or less by the size, shape, and compactness of the individual grains.

The terms fusible and refractory have been given different arbitrary values by different authors. Ordinarily a clay is said to be very fusible when it melts at a low temperature,— say from 800° F. to 1800° F., and refractory when it withstands a temperature of 2400° F. and above. However, owing to the fact that a clay which is refractory for one purpose may be fusible for another makes it impossible to fix any arbitrary temperature above which all clays are refractory and below which they are fusible.

The difference between the temperature of fusion and that at which incipient vitrification takes place depends mainly upon the composition of the clay. The temperature of scoriaceous vitrification of a very calcareous clay is often not over 75° F. above that of incipient vitrification. In the case of some of the kaolins the temperatures of fusion and incipient vitrification are as much as 500° F. apart.

In order to insure vitrification of the ware in all parts of a kiln, there should be a free range of temperature of at least 150° F., with no danger of melting in any part of the kiln. It is not possible to heat all parts of a kiln to a uniform temperature, and if there should be a difference between the coldest and hottest parts of the kiln, greater than the difference between the temperatures of incipient and scoriaceous vitrification, a portion of the ware will be either over or under burned. To successfully burn a kiln of paving brick, for example, the temperature should be raised to a point which will insure complete vitrification of the brick in all parts of the kiln without melting any of them. The greater the range of temperature between the points of incipient and scoriaceous vitrification the easier it will be to burn successfully the kiln of brick.

Alumina, except when present in large amounts, decreases the fusibility of a clay. Ordinarily, fusibility decreases as the percentages of silica and alumina increase. Fusibility increases, in general, with the increase of the bases,—potash, soda, iron, calcium, manganese, and magnesium. Wheeler[1] says, "The alkalies are more readily fusible than the ferrous oxide, which latter is more fusible than lime, and lime more fusible than magnesia. Again, a mixture of bases is more fusible than a single base, and the greater the number of bases, the greater the fusibility." Keeping in mind the shape, fineness, and compactness of the grains one can determine approximately the fusibility of a clay from a knowledge of the chemical and mineralogical compositions.

The fusibility of a clay can be determined directly by the use of either a standard pyrometer or standard pyrometric

[1] For a fuller description of this subject see Report of Missouri Geological Survey, Clay Deposits of Missouri, Vol. XI, p. 146, H. A. Wheeler.

cones, such as have been proposed by Seger. It is thought that the cones used by Seger and added to by other workers are better adapted to most practical uses than a standard pyrometer. The cones are mixtures of clays and are arranged in a series, the lowest of which fuses at 1310° F. and the highest at 3956° F. Each cone represents a difference in temperature of from 34° to 52° F.[1]

These cones are made in this country by Professor Edward Orton, Jr., of Columbus, Ohio, and are now being used very generally by pottery manufacturers throughout the central and eastern states.

[1] For a fuller description of this subject see Report of Missouri Geological Survey, Clay Deposits of Missouri, by H. A. Wheeler, Vol. XI, pp. 129–152.

CHAPTER V.

CLAY DEPOSITS OF WISCONSIN.

The clay deposits of Wisconsin are both residual and transported. The transported clays are the most extensive and occur in nearly all parts of the state. The residual clays are less abundant and occur only in the driftless area and in such places as were protected by the overlying formations from erosion during the glacial period.

RESIDUAL CLAYS.

The main kinds of rock which contribute through their decomposition to the mass of clays in Wisconsin, may be conveniently grouped as follows:

1. Granite and Gneiss.
2. Greenstone and Allied Basic Eruptives.
3. Limestone and Dolomite.
4. Sandstone.
5. Shale.

The granite and other *igneous rocks* which now occur at the surface in a practically unaltered condition must have been disintegrated to a very considerable depth prior to the glacial period. They had, in part, at least, been exposed to the atmosphere from Paleozoic to Pleistocene time. The ice sheet which passed over their exposed surfaces during Pleistocene time removed most of the decomposed rock, ground it into flour, and deposited it over an extensive area to the southwest. Wherever the detritus was deposited directly from the ice it was unassorted and consists of intermingled boulders, pebbles, sand and clay. Where the rock flour was caught up by the waters of the melting glacier it was generally mingled with debris from many sources and deposited in a mass which may have had a very different composition from that of any of the rocks from which it was derived.

The decomposition of the igneous rocks near the contact of the northern crystalline area and the Potsdam sandstone has been in progress since Paleozoic time and has extended in many places to a considerable depth underneath the porous sandstone with which it is covered. The erosion accompanying the advance of the glaciers removed most of the decomposed rock which was not covered with the sandstone strata, but where glaciation was not severe or the deposits of till heavy, there still remain in this region decomposed schistose or granite rocks rich in kaolin. These schists or shales as they are sometimes called outcrop mainly along the river and stream channels which have been cut through the sandstone and shale into the hard, undecomposed rock below. These shales have been observed from Stevens Point to Chippewa Falls at places where the larger streams have cut their channels through the sandstone to the schistose rocks below. They have not been traced continuously over this region but are known to occur in broad belts at several places. The crystalline complex of which they are the decomposed equivalent is composed of many varieties of igneous and possibly clastic rocks, each having a different mineralogical composition. As the proportions of feldspar, mica, quartz, hornblende, pyroxene, iron oxide, etc., vary in the original rock, so do the percentages of aluminum, silicon, potassium, sodium, calcium, iron, etc., vary in the decomposed equivalent. In some places the schist is almost pure kaolin, while not far distant under the same conditions it may have a high percentage of quartz and iron oxide.

It should be understood, however, that the mineral salts carried in solution by the percolating waters, may have a decided influence over the amount and kind of mineral substances that are removed from the igneous rocks which are being transformed into the schists. Among the schists the mineralogical as well as the chemical composition is much diversified, although it is plainly evident that the percentage of kaolin decreases from the place of contact with the sandstone to the undecomposed rock below.

The shales in this region have always been found either near to or within the bed of a stream. In some places they are exposed immediately at the surface but in most cases they are covered with an indefinite thickness of river gravel or sandstone. How far these shales extend underneath the sandstone is a matter which has not been determined and which cannot be positively settled without making borings. It is believed, however, that the beds are very extensive.

The Greenstones and allied basic rocks when decomposed usually form a very ferruginous clay or shale. Ferruginous clays formed by their decomposition occur in several localities along or near the southern border of the crystalline rocks. Ordinarily they are high in silica and iron oxide and below the average in aluminum. The percentages, however, vary greatly with the composition of the rock of which they are the modified equivalent.

Limestone and dolomite usually contain small percentages of aluminum, silicon, and iron, all of which are much less easily decomposed than the calcite or dolomite of which the rock is mainly composed. The calcite and dolomite are constantly being taken into solution and removed by underground waters, leaving a residual deposit of kaolin, quartz, and iron oxide with a greater or less amount of calcium and calcium magnesium carbonate. This residual deposit is a clay which varies widely in composition depending on the composition of the rock from which it has been derived. It may be rich or poor in kaolin, high or low in quartz, and contain variable amounts of iron oxide, calcite, and dolomite.

Deposits of this origin occur abundantly in the driftless or non-glaciated area in the southwestern part of Wisconsin. The residual deposits which formerly occurred above the limestone formations within the glaciated region have been largely removed through glaciation. The residual deposits in the southwestern part of the state occur mainly on the tablelands and flat topped ridges, where the rivers and streams have not been sufficiently active to remove the products of disintegration. In some places they attain a thickness of thirty or forty feet.

Sandstone is composed very largely of quartz. Its decomposition, therefore, does not contribute very greatly to the formation of clay. The weathering of sandstone is mainly in the form of disintegration and the residual deposits are largely sand. The percentage of kaolin in sandstone is so small that it is not ordinarily classified as a clay forming rock.

Shale, used in the sense of a sedimentary rock, usually contains all the elements found in an alluvial clay. It may contain large or small amounts of kaolin, quartz, iron, calcium, etc. These constituents may occur in proportions which make the clay admirably suited to the manufacture of one or more of the various clay wares, or the composition may be such that the clay is little suited for the manufacture of anything.

A shale is in itself a consolidated clay and must be pulverized by weathering or grinding before being used. When decomposed or disintegrated it forms a clay which does not differ materially in composition from the shale itself. If removed by running water and re-deposited, the composition of the new clay may be very different from that of the shale, on account of the introduction of materials from other sources.

TRANSPORTED CLAYS.

The clay which forms on the tops and slopes of hills and ridges through the decomposition and disintegration of the rocks moves slowly into the adjacent valley. It is first moved by freshets aided by the force of gravity and is usually deposited in a somewhat heterogeneous semi-stratified mass near the bottom. As a result of these movements of residual deposits it is a common thing to find a valley filled to a considerable depth with the clay from the neighboring slopes.

The rocks of adjacent hills are often of several kinds, as in the driftless area in the southwestern part of Wisconsin Many of the ridges in this part of the state consist of both sandstone and limestone, each of which contributes its share to the clay deposits of the adjacent valleys. In this way it often happens that the composition of the clay deposits varies with the areas of exposed sandstone and limestone which are within the catchment basin of the rivers or lakes by which they are formed. These deposits of clay are not strictly residual or sedimentary. They are intermediate between the two.

Glacial Clays.—The glacial clays are distributed irregularly over a greater part of the glaciated section of the state. Wherever a terminal, lateral, interlobate, or ground moraine occurs, more or less glacial clay is found. This clay, however, is usually mixed with pebbles and boulders of various shapes and sizes, on account of which it is unfit for commercial purposes. Clay which contains only scattering pebbles or boulders is sometimes used by passing it through a crusher, whereby the large stones are removed and the smaller ones ground into a powder. In case the clay contains none but large boulders these are frequently removed by hand. The clay is sometimes shoveled from between the boulders which are left standing in the field.

In some instances the clay which was deposited directly from the ice has been more or less modified by subsequent water action. To what extent this has occurred in any particular place it is often difficult to determine.

Deposits from water.—The most extensive deposits of clay within the state are those which have been formed by water. The *marine deposits* of Wisconsin consist of the shales known as Cincinnati, which extend in a narrow belt through the eastern part of the state, and the shale beds which are interstratified with the sandstone of the Potsdam formation in the central and northern parts of the state.

The Cincinnati shale has a thickness of from 165 to 240 feet and consists of interbedded limestone and shale. It varies widely in composition, ranging from a very pure clay to one which contains a large amount of iron, quartz, calcite, and dolomite. In some places it is but slightly indurated and at others it is very hard and almost a slate. The percentage of limestone in the formation increases as it is followed northward toward Sturgeon Bay.

The shale which occurs near the base of the Potsdam formation in the central part of the state consists mainly of interbedded layers of very soft plastic clay and coarse sandstone. The clay layers are in some places blue and in others a deep reddish brown color. They have a maximum observed thickness of twenty inches. The shale which occurs interbedded with the brown sandstone of the Lake Superior region occurs in thin reddish brown laminae. It has a maximum thickness on the St. Louis river of twelve feet.

The *lacustrine clay deposits* are, perhaps, the most extensive of all of the Wisconsin clays. They are not as widely distributed as the glacial clays but in many places they attain a greater thickness, being surpassed in this respect only by the Cincinnati shales.

The lacustrine clays are supposed to have been formed during the successive advances and recessions of the ice sheet of the glacial period. Prior to and following the last glacial epoch the combined area of lakes Michigan and Superior is supposed to have n much greater than at the present time. Green Bay extended for a considerable distance to the southwest, merging with Lake Winnebago, and to the east and north it is thought to have united with the waters of Lake Michigan. At this time Green Bay was doubtfully separated from Lake Michigan by a narrow strip of relatively high land where the Kettle-Moraine now occurs in Kewaunee, Brown, and Manitowoc counties.

In the neighborhood of Racine the lacustrine deposits show that Lake Michigan extended about eighteen miles west of the present shore line. Farther north, in Ozaukee county, the deposits are very much narrower, having been observed only about two or three miles west of the present shore line of Lake Michigan. At Sheboygan the clays extend fully fifteen miles west of the present lake shore. The waters of Green Bay completely inundated Door county and covered portions of Manitowoc, Calumet, and Fond du Lac counties. To the west the waters of the bay covered a large part of Green Lake, Waushara and Waupaca counties. To the north as far as Shawano the waters flooded the region adjacent to Wolf River, and at Oconto the deposits indicate that the bay extended eighteen miles west of the present shore line.

Adjacent to Lake Superior the lacustrine deposits indicate that the shore was at that time fifteen to eighteen miles from its present location.

Well borings in the vicinity of Milwaukee and at other places near Lake Michigan, show that the deposits of clay and interbedded till have in some places a depth of one hundred or more feet. This thickness is not composed entirely of water assorted material but has interlaminated with it a considerable thickness of boulder clay in which are imbedded many hard pebbles of igneous rock and limestone.

The clay of the upper or weathered portion of these lacustrine deposits ordinarily has a reddish brown color while the clay of the lower beds usually has a dull bluish or pinkish color. The approximate extent of these clays is shown on the accompanying map, which has been compiled partly from a map of the former Geological Survey of which Professor T. C. Chamberlin was director.*

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*For a fuller discussion of these lake clays the reader is referred to the Geology of Wisconsin, Vol. II, pp. 219-239.

The third deposit from water which has been recognized in this report is that formed by *streams.* It is apparent from observation that many of the larger rivers in the state had cut their channels very much deeper prior to the glacial epoch than they are at the present time. Contemporaneous with the formation of the lacustrine deposits just described, the river valleys were at different times flooded with water becoming estuaries of the lakes and ocean. In the quiet water of these estuaries far back from the lakes and ocean, there were deposited considerable thicknesses of clay. At the present time remnants of these deposits are found along the Fox, Wolf, Rock, Wisconsin, Eau Claire, Chippewa, Black, Red Cedar, and many other streams in the eastern, western, and southern parts of the state. These deposits are usually thinly laminated and have a maximum thickness of from fifty to one hundred feet. Their composition is more variable than that of the lacustrine clays. In some places they are highly calcareous and in others the calcium is very low. The percentage of silica and alumina also varies with the catchment area of the stream along whose course the deposits were formed.

Besides the river deposits of this age, much later deposits of clay have formed in the valleys of many of the more important streams of today, especially where the tributaries are fed from regions heavily covered with glacial drift or where they pass through rock which is largely decomposed. At the present time most of the rivers are cutting their channels deeper and only where the streams, laden with silt meander through swamp lands or discharge their loads into a lake or other reservoir are deposits of clay being formed.

The deposits which occur in the river valleys in the southwestern part of the state and those that are found throughout the glaciated region of the eastern part are very calcareous. Those in the west central part, where limestone is not the predominant rock, are but slightly calcareous. The clays along the rivers in the extreme northern part of the state have been permeated with calcium carbonate derived from the limestone and marble which occur farther to the north. Limestone gravel is found abundantly in the very calcareous clays, having been transported from the limestone region either by the glaciers or the waters of the lake and thus disseminated throughout the body of the clay. The beach deposits which occur within the body of the clay consist largely of sand and limestone gravel.

In Dunn and St. Croix counties, in the western part of the state, there are considerable quantities of pure, white kaolin, which is thought to have been derived from the decomposed igneous rocks which occur northeast of this region. This kaolin is supposed to have been deposited by water prior to the first glacial epoch. The extent of the deposits has never been accurately determined, although it is known that they cover a very large area. They are interbedded with layers of sand and occur underneath a considerable thickness of till or boulder clay. The level of these kaolin beds is about 200 feet above the estuarine deposits referred to above.

It is very certain that these deposits were formed prior to the last glacial epoch and there are good reasons for believing that they antedate the first advance of the ice sheet. The reason for believing this, is that the deposits are now covered with boulder clay which is thought to belong to the first glacial epoch. Further than this, the layers of clay are often crumpled, folded and broken to a considerable depth below the surface.

Wind deposits.—There are few deposits of clay in this state that can be said to have had their origin strictly through the action of wind. The clays which occur along the Wisconsin river near Okee and Merrimac are often spoken of as loess deposits. This, however, if it signifies that they were wind borne or wind deposited, is a misnomer. I am inclined to believe that these clays have been both transported and deposited by water and that they were formed contemporaneously with the lacustrine deposits. At many places on the tops of the highest bluffs or ridges near the Mississippi river occur deposits of arenaceous clay which Professor T. C. Chamberlin believes to have been wind borne. These deposits are often closely associated with clays which are known to be of residual origin, and it is frequently difficult to differentiate the two deposits. These so-called loess deposits have not been developed very extensively in Wisconsin for brick manufacturing. They are of a quartzose nature and usually occur in unfavorably situated localities.

RESUMÈ.

There are few places in Wisconsin where a clay of one nature or another cannot be found. Even along the rivers that traverse the sandy land of Adams, Juneau, and Jackson counties, clay is found in considerable quantity. The clays are not uniform in composition or texture over any considerable area but differ locally, depending upon the source of the materials of which they may be composed.

The clays of the extreme northern, eastern, and southern parts of the state are very calcareous; those of the southwestern, western, and north central sections are moderately calcareous; and those of the central section bordering on the crystalline rocks are low in calcium. The kaolin deposits which occur in the western and central portions of the state are the richest in aluminum and will rank among the highest grade clays on the continent. The shales which are the decomposed equivalents of the igenous rocks are next highest in the percentage of aluminum. The residual limestone, glacial, stream, lacustrine and loess clays are all moderately low in aluminum. Some are higher than others and constitute exceptions to the general rule. The clays that are low in calcium and magnesium, with the exception of the schists and kaolin, are ordinarily high in quartz.

The deposits in each locality are moderately extensive and will be considered in detail in Chapters VII to XIII inclusive.

CHAPTER VI.

METHODS OF MANUFACTURING BRICK AND DRAIN TILE IN WISCONSIN.

MINING THE CLAY.

The method of removing clay from the bank will depend mainly upon the manner of occurrence and the facilities at hand for mining. In places the clay occurs below the general level of the land and in other instances it occurs above. In the former case it is necessary to mine the clay and elevate it to the surface and then to the factory, while in the latter instance the clay has only to be loosened from the bank and transported to the factory. In the first case artificial power must be supplied to transport the clay and in the latter case the power is often supplied by gravity.

In case it is necessary to elevate the clay in transferring it from the bank or pit to the works several different methods may be employed. The common method is to haul the clay in carts, wagons, or cars, by horses or cable and winding drum up an incline to the factory. In a few places the clay is elevated in buckets by means of derricks and transported on dump carts or cars to the factory. Occasionally the bank is worked at an angle of twenty or thirty degrees and the clay is plowed and removed by means of wheel scrapers.

In any case, it is more expensive to work a clay bank which occurs in a place where power must be supplied than to work one from which the clay can be transported to the factory by gravity.

Clay which forms an escarpment along a river or which occurs above the general level of the land forms what is ordinarily known as a clay bank. The method of working one of these banks will depend mainly upon the size of the factory which is located at the place in question. The simplest method is to loosen the clay from the bank by means of picks and shovels, lift it into wheelbarrows or dump cars, and thus transport it to the factory. Frequently dump cars run by cable and winding drum are substituted for carts hauled by horses. Dynamite is frequently used to loosen tough banks of clay and in this way large masses are often thrown down. In some instances the clay is loosened by means of water which is poured into a narrow ditch which has been dug some distance back from the face of the bank and parallel to it. A steam shovel is employed at several of the yards in Wisconsin to remove the clay from the bank, but most of the brick factories in Wisconsin are too small to utilize to advantage such expensive machinery.

The sedimentary clays in Wisconsin, as in most other states, vary considerably in different parts of the bank. The upper layers are frequently much more quartzose than the lower or vice versa. Beds of sand frequently separate the clay bank into two or more parts. Wherever the clay bank varies in this manner it is ordinarily worked to such a depth that when thoroughly mixed it will contain the proportions of sand and clay which will make the strongest and most durable building brick. Where the clay has essentially the same percentage of sand in all parts of the bank it is generally worked either to the water level or to such a depth that it can be removed without the necessity of elevating any considerable distance.

WEATHERING THE CLAY.

The second step in the utilization of clay, after removing it from the bank, is to subject it to a process known as weathering. Many of the clays when they are first taken from the bank slack very slowly when immersed in water. Sometimes it requires several days for a clay to absorb enough water to fit it for mixing in the pug mill. However, at many of the plants in Wisconsin no attention is paid to weathering and the clay is removed directly from the bank to the pug mill where it is mixed with water and tempered. Some of the brick manufacturers in Wisconsin have learned by experience that much time is saved and better brick are manufactured if the clay which they are using can be mined in the fall, hauled to the surface, and allowed to weather during the winter before being used. Clay which is spread out at the surface of the ground and allowed to freeze and thaw during a season is ordinarily in a much better condition to work than that which remains in the bank. It is a very great advantage to allow the shales or decomposed schistose rocks, which are mined in some portions of the state, to remain exposed to the atmosphere at least six months before using. The hardest shales can frequently be worked almost as easily as the soft plastic clays after they have been subjected for a season to freezing and thawing.

In some cases the clays are plowed and allowed to stand from twenty-four to forty-eight hours before being removed to the tempering mill or soaking vat. During this time the clay has an opportunity to dry and is thereby reduced to a condition in which it will absorb water and slack much more readily than if it were taken directly from the bank.

REMOVING CLAY FROM THE BANK.

The man who has charge of removing the clay from the bank has one of the most important positions connected with a brick factory. He should know the character of each of the different layers which compose the bank which he is working, the manner in which each burns, the proportions of sand and clay in their composition, the color of the clay when burned, the effect of weathering, and in fact he should be familiar with all the characteristics of the clay in all parts of the bank. Some of the clay banks in Wisconsin consist of clay which burns red in one part and white or buff in another. The man who has charge of removing the clay from such a bank should know the exact limitations of the red, white, and buff burning clays and deliver the clay to the factory in such shape that there will be no question as to what the color of the burned product will be. If the superintendent of the plant desires clay which will burn a bright cherry red the foreman of the clay bank should be able to furnish that which will produce the desired color *without any guess work.* If white or buff burning clays are desired he should also be able to select these with equal facility.

By using different proportions of red and white burning clays it is possible to produce many intermediate shades and the foreman of the bank should be sufficiently familiar with the results of mixtures of these two clays so that he can furnish the clay to the factory in such proportions as to give any desired result.

If it is intended to weather the clays they should be taken from the bank and kept separate from one another until used. In the manufacture of dry press brick it is customary to mine the clay and thoroughly dry it underneath sheds before using. When the clay is soft and plastic it is frequently plowed and harrowed before removing to the sheds for drying. The best device for removing clay from the bank is the wheel excavators which remove only the dryest portions from the surface of the bank.

SOAKING AND MIXING CLAY.[1]

In the manufacture of all kinds of brick with the exception of dry press it is necessary to mix the clay with a greater or less quantity of water. To make a soft mud

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[1] Some clay contains gravel or hard lumps on account of which it is frequently advisable to pass it through a crusher or disintegrator before mixing.

brick from a given clay it will require a definite quantity of water for each cubic yard of clay. The water required to give another clay the proper consistency for a soft mud brick may be greater or less depending upon the character of the clay.[1]

For the manufacture of stiff mud brick the proportions of clay and water may be very different from what are required in the case of soft mud brick but will depend again upon the character of the clay in question. It has been demonstrated that it is unsatisfactory to remove the clay directly from the bank to the factory and only give it the mixing which is provided by the pug mill connected with most stiff mud machines.

Complaints are frequently entered against the stiff mud or auger machine brick, in which the complainants assert that brick which are thus made are so laminated that they weather rapidly when exposed to the atmosphere. Stone masons also experience difficulty in breaking the brick so as to obtain square ends. Such complaints are very common and it has been observed that in many instances they are well founded. The reason for the lamination upon which the rapid deterioration depends is due mainly to the manner in which the clays are prepared. There is perhaps no process in the country by which a better and cheaper brick can be made provided the clay is thoroughly mixed before moulding.

The commonest method of mixing clays in this state is to construct two large vats, which are filled on alternate days. If sand is mixed with the clay it is added in thin layers between the mass of clay. Upon this an indefinite quantity of water is poured and the whole is allowed to soak from twelve to forty-eight hours. The clay is then taken from the vat and either shoveled into a pug mill operated by horse power or steam or into a pug mill con-

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[2] The kind of machinery used will also control more or less the quantity of water which it is necessary to use.

nected with a brick machine. By soaking over night the clay should absorb sufficient water so that no additions will be necessary during the process of pugging. Soaking clay in this manner before mixing is very beneficial and frequently necessary.

In some of the factories the clay is passed through two pug mills in the process of mixing before it is received by the brick machine. When the clay is thus worked it usually makes a solid brick which is free from lamination of any kind. When the clay is moved directly from the bank to the pug mill and water is added to the clay immediately before it passes into the machine the result in the case of an auger machine is almost sure to be a laminated brick. There are very few clays that can absorb water with such rapidity that it will be equally distributed through the clay in the time which is required for the clay to pass from one end of a pug mill to the other. The clay which first receives the water becomes soft and slippery and in passing the length of the auger the softer parts slide by one another causing the lamination for which the stiff mud brick have been so often condemned.

Another method of mixing the clay is by using a tempering wheel. For this purpose the clay is placed in a large circular vat, the necessary amount of water is added and the whole is allowed to stand over night. The next day a wrought iron wheel, consisting of one or two rims and as many as sixteen spokes is placed in the vat and revolved on a shaft through the mud. The wheel may be operated either by steam or horse power. "By an automatic arrangement of the rod and pinion the wheel is drawn back and forth on the shaft, changing its position with each revolution and reversing itself both at the outer and inner edge of the pit."

A wheel of standard size has a diameter of six feet. The clay is usually mixed with a tempering wheel for about half a day but the length of time to fully prepare the clay will depend largely upon the character of the clay. This method of mixing the clay is somewhat more expensive than the pug mill on account of the additional times that the clay must be handled. I believe, however, that of all the more common methods for tempering clay that have come under my observation this is perhaps the most satisfactory.

Another method of tempering clay is in the wet pan. This method is not ordinarily employed for the manufacture of common brick, although it is used almost exclusively in the preparation of clay for the manufacture of pottery. The wet pan is one of the best methods for thoroughly mixing and tempering clay to a uniform body that has been devised. The heavy wheels that move over the clay in the pan grind all hard lumps into a power while the clay is at the same time thoroughly mixed and the water content well distributed.

Too often the clay which is used for the manufacture of brick is transferred to the machine before it has been properly prepared. A thorough mixing and tempering of the clay is one of the most essential requisites for the manufacture of good brick. It is not possible to manufacture the best quality of brick from any kind of clay until one appreciates the importance of thoroughly working the clay before transferring it to the machine. If the clay is worked in a wet pan, care should be exercised not to over grind the clay whereby it sometimes loses part of its plasticity.

GRINDING THE CLAY.

Crushers, disintegrators, and pulverizers.—Shales are sometimes so hard that it is necessary to reduce them in a crusher, disintegrator, pulverizer, dry pan, or wet pan before they can be suitably tempered or soaked with water. In some instances clay contains gravel or other hard nodular substances that must be either removed or pulverized before the clay is in condition for manufacturing purposes. For the manufacture of brick as well as pottery the particles composing the clay should be approximately uniform in size. The best way to secure this condition is by grinding the clay in a dry pan and passing it through a screen. The dry pan reduces the larger fragments to a powder while the screen assorts the particles allowing only those under a definite size to pass into the machine. The crusher, disintegrator, and pulzerizer are used in many of the Wisconsin yards for either reducing or removing gravel which occurs in the clay. These devices serve an excellent purpose and work well when new. However, they wear out rapidly and often within a few years are inefficient in their operation and must be repaired or replaced by new machines. Nevertheless, where limestone or other kinds of gravel occur in the clay it is necessary either to remove that portion of the bank in which the gravel occurs or use some kind of machinery by which the gravel may be removed. The clay is usually passed through a crnsher or disintegrator before it is tempered in the pug mill. Sometimes two sets of crushers or disintegrators are required to insure the complete removal or disintegration of the gravel.

The pebbles found in clay usually vary in size from those which are no larger than the particles composing the body of the clay to those several inches or more in diameter. They may be any kind of stone and will always seriously interfere with the manufacture of the brick unless carefully disposed of as above suggested. The utmost care should be exercised to remove or reduce to a powder any gravel which may occur in the clay which is being used.

In case the clay is free from gravel but is very hard or contains tough nodular parts it is sometimes advantageous to pass it through a crusher. However, a wet pan or a dry pan used in conjunction with screens is usually more desirable.

METHODS OF MOULDING.

Brick are manufactured either by hand or by machinery. There are two kinds of hand-make brick, known as "sand moulded" and "slop" brick. The sand moulded brick are made in wooden moulds which are first sanded, and the slop brick are made in steel lined moulds which are dipped in water instead of being sanded. One, two, three, or four compartment moulds are usually employed in making brick by hand. In the manufacture of sand moulded brick by hand the clay is frequently rolled in sand before being placed in the moulds.

Machine made brick are known as either soft mud, stiff mud, or dry press, depending upon the process employed in their manufacture. Soft mud brick are manufactured in presses operated by a plunger. Six compartment moulds are used almost universally and are always sanded before inserting in the machine. Machinery employed for this purpose is operated either by hand, horse, steam, or other power. The clay used for the manufacture of these brick is usually softer than that employed in the manufacture of stiff mud brick. The stiff mud brick are manufactured out of clay which contains less water than that which is used for the manufacture of soft mud brick and are consequently termed stiff mud. The brick are seldom sanded and have smooth sides except where they are cut off. All machine and hand made brick with the exception of slop brick are frequently repressed. Before repressing the soft mud brick they should be dried until about as firm as the stiff mud brick are when they come from the machine.

Dry press brick are manufactured in a special machine in which the clay used is brought to various degrees of dryness. The condition of the clay when used depends entirely upon the manner in which it works in the press. Some clays can be used successfully in a dry press when they are very dry but others cannot be worked to advantage unless they are very damp. In a dry press machine the clay is subjected to a very high pressure and the particles composing the brick are moved close together. Some clays will retain their shape when subjected to a very high pressure while others crack or burst when the pressure is released. Dry pressed brick usually have very smooth faces and sharp corners, which characteristic is often lacking in soft or stiff mud brick unless repressed.

Resumè.

Experience has shown that stiff mud brick can be made more rapidly and with less expense than any other kind. The capacity of the stiff mud machine is ordinarily much greater than that of either the soft mud or dry press machines. If the clay used for the manufacture of the stiff mud brick is properly tempered before being used, the brick will be of good quality and the expense of manufacture will be less than that of other kinds of brick. Soft mud brick can be made by machine almost as cheaply as stiff mud brick while the dry press and re-press brick are the most expensive of all.

One of the advantages in manufacturing dry press brick is the fact that the brick made by this process do not require drying before burning. The dry or semi-dry pressed brick are usually stacked in the kiln immediately after removing from the machine. By this method one of the steps in the manufacture of stiff or soft mud brick which often occasions very considerable loss is entirely done away with.

METHODS OF SANDING BRICK.

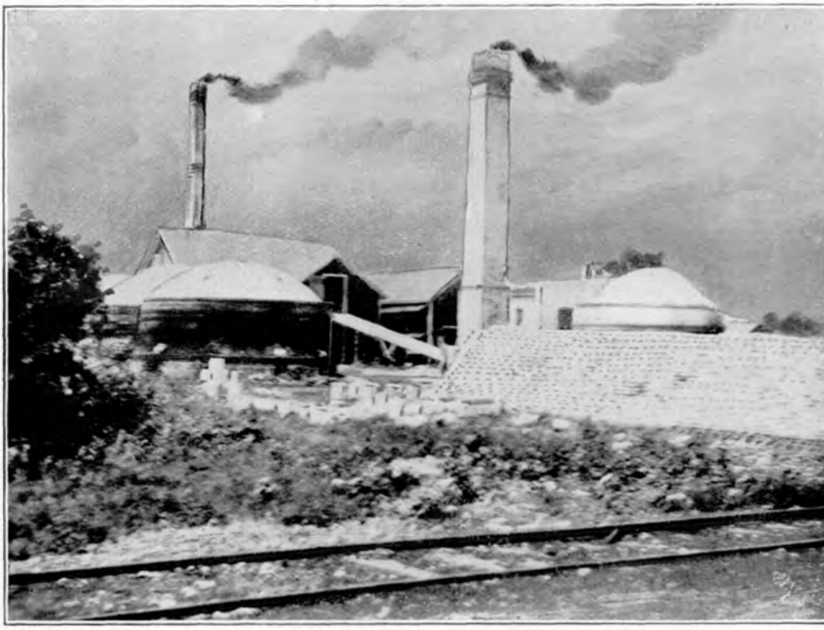
In the manufacture of soft mud brick, either by hand or machine the moulds are usually dipped in water, filled with sand, and emptied each time before they are used. In this way the interior of the moulds are covered with a thin layer of sand which adheres to the wet surfaces. The filling and emptying of the moulds with sand is done either by hand or machinery. An automatic sander is a labor saving device which is now a part of every well equipped plant. In some of the yards in which the brick are made by hand the block of clay is rolled in sand before being placed in the moulds.

In the manufacture of "slop" brick the moulds are not sanded but the brick are usually sanded after being dumped on the yard. The stiff mud brick when dried in hacks are also often sprinkled with sand to prevent the brick from sticking together when piled on top of one another.

To prevent the block of clay from sticking to the table over which it passes in coming from the die of an auger machine, the table is usually covered with a thin coat of oil. This not only prevents the clay from adhering to the table but also gives the block a smooth even surface.

DRYING BRICK.

The brick which are manufactured by hand or in stiff or soft mud machines must be dried before stacking in the kiln. In general, three methods of drying are in common use throughout the country. The first method, and that which is most commonly employed in Wisconsin, is by hacking the brick on the yard. By this method the moulds containing the brick are removed from the machine and carried to the yard and there dumped. During favorable weather the brick are allowed to remain flat on the yard for a period of a day, after which they are stacked on edge in piles known as hacks. After being hacked to a height of ten or twenty brick they are allowed to remain exposed to the air for a period of from one to two weeks. If conditions are favorable and the yard does not suffer from extreme heat, frost or wet weather, the brick will dry uniformly and be in excellent condition when placed in the kiln. In case storms prevail during this period the brick dry much more slowly. They are usually protected on the top by board saddles and along the sides by stretches of canvas or boards. These are only emergency methods of



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JEFFERSON BRICK AND TILE COMPANY, JEFFERSON.

FIGURE 1.—VIEW OF KILNS AND FACTORY. FIGURE 2.—ONE OF THE KILNS.

protection and can only be used when the foreman is a sufficiently good weather prophet to apprehend approaching storms. It frequently happens that a storm comes up so suddenly that the hacks cannot be covered, or again in the night when no one is about. In this way thousands of brick are annually destroyed through wetting and overturning of the hacks.

Many of the brick which are exposed to the direct rays of the sun are cracked and warped by extreme heat. During the fall when the temperature lowers to the freezing point many thousands of brick are lost annually in Wisconsin brick yards, owing to the inadequate facilities for protection against such changes of temperature.

Where the brick are not piled in hacks on the yard they are usually dried on pallets under sheds. The pallets frequently consist of a single ten inch board, although the better equipped yards have pallets which are made out of four to six narrow strips with cleats at both ends and in the middle. These pallets are erected in tiers under sheds especially constructed for this purpose. Brick which are placed on pallets should dry more quickly than those in hacks, owing to the better circulation of air and the fact that they are above the ground. Brick that are dried on pallets are not in as great danger from extreme heat or rain as those piled in hacks on the yard. A few of the brick upon the windward side of the yard are sometimes destroyed, but, as a rule, these are protected by boards which are supplied temporarily for that purpose. Under favorable conditions it requires from seven to twelve days to dry brick on pallets. Brick dried in this manner are frequently in as great danger from frost as those that are hacked on the yard.

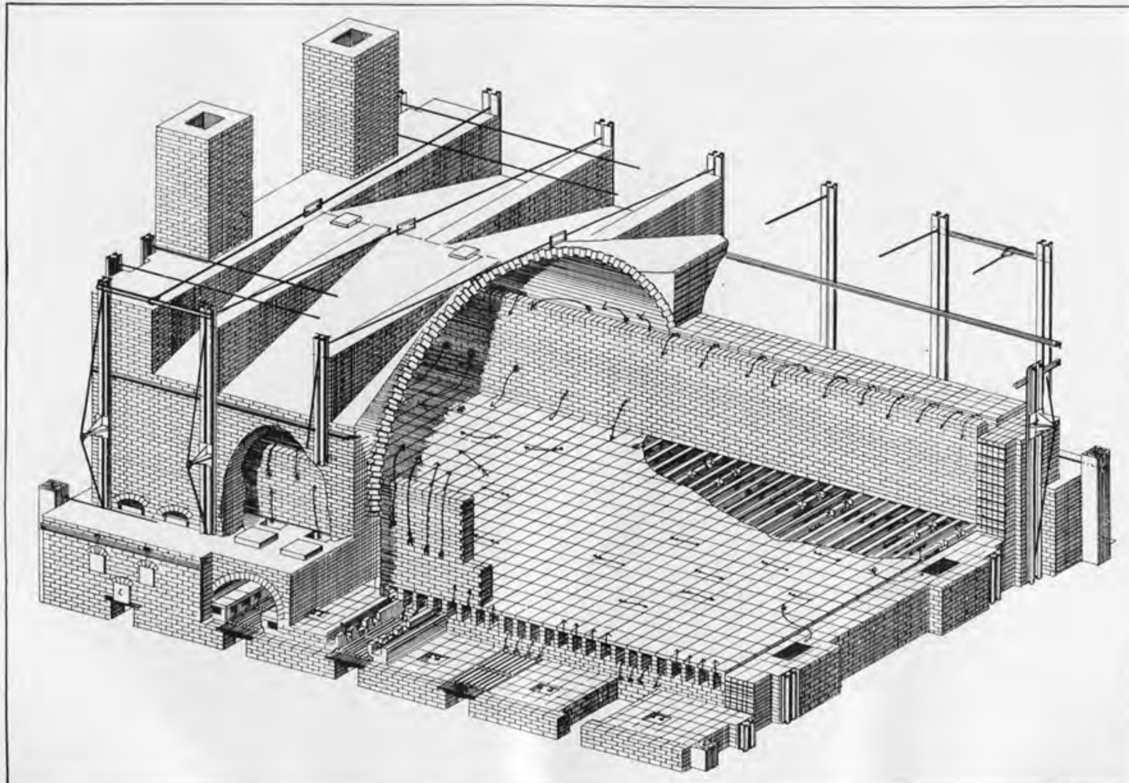
The third method of drying brick is by the use of artificial heat. There are three classes of patent driers which are distinguished from one another by the manner and condition in which the heat is supplied. The first class of drier furnishes direct heat through the consumption of coke or coal; the second class provides heat through radiation from steam pipes; and the third class uses direct heat conveyed from and supplied by the kilns used in burning the brick.

Very few patent driers are now being used in the brick yards of Wisconsin. All that have thus far been erected are of either the steam or coke type. Driers of these, as well as the third type, are frequently equipped with fans to provide a constant and uniform circulation of the hot air from one end of the dry shed to the other. The steam and coke driers have frequently been objected to on account of the difficulty experienced in maintaining a uniform heat. This objection of course would also hold against the third class of drier. However, these two methods ordinarily require the consumption of extra fuel and it is for this reason more than any other that they are being abandoned by the larger plants in favor of the third class of drier.

For large plants the drier which uses hot air from the kilns is perhaps the most economical construction now in use. Some of the modern brick yards such as that owned by the Purington Paving Brick Company of Galesburg, Illinois, are provided with this kind of a drier. The hot air is forced by means of a fan from the kilns through the conveyors into the drier. The hot air enters at one end of the drier and is expelled at the other. The brick enter the drier at the end from which the air is expelled, thereby coming in contact, at first, with a moisture laden atmosphere having only a moderate temperature. After entering the drier the brick are moved gradually through the kiln toward the other end, the temperature increasing pari passu with the movement.[1]

It requires from twenty-four to thirty-six hours for the brick to pass through the drier and come out at the other end in condition so that they can be immediately transferred to the kiln and burned.

[1] The principle upon which the different dry kilns are operated can be learned in greater detail by application to the manufacturing concerns that are placing them on the market.



SQUARE DOWN DRAFT KILN.

A brick plant which is equipped with a drier of this character has a decided advantage over one which is dependent entirely upon the natural air. Plants which are equipped with driers can begin operations earlier in the spring and work later in the fall than those that depend upon hacks and pallets for drying their product. If one is intending to construct a modern plant it is very necessary that it should be equipped with a drier in order to manufacture the brick quickly and economically.

It must be understood, however, that there are many localities where the conditions are such as not to warrant the construction of a dry kiln. Where the demand does not call for the manufacture of over a million brick a year, a person would scarcely be justified in considering the erection of a special drier.

METHODS OF BURNING.

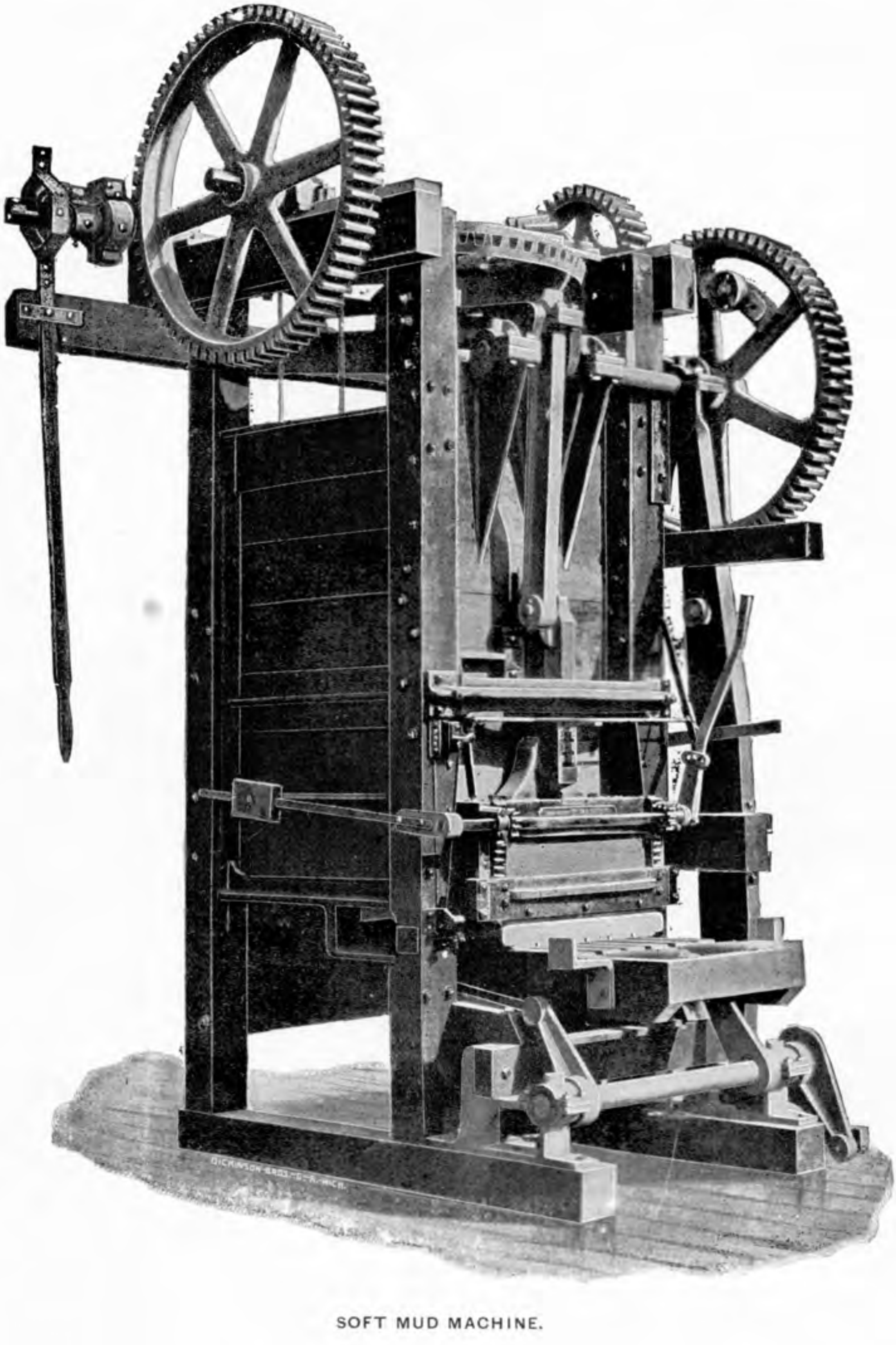
After the brick are dried they are removed to the kilns and stacked where they are burned. Two general types of kilns are in common use, known as the up draft and down draft.[1] The up draft kilns are known as scove or permanent, depending upon whether the walls are temporary or permanent.

The Up Draft Kilns.—The brick at all the small yards are almost invariably burned in up draft kilns of the scove type. With this kind of a kiln the brick are ordinarily stacked first and the walls constructed later. The kiln is usually covered with a roof constructed either out of wood or sheet iron. The kiln is protected on two sides with an open shed underneath which the wood used in burning is piled. The walls of the scove kiln are ordinarily constructed out of broken brick which are cemented together with mud. In order to keep the walls intact and reasonably free from

[1] A third kind known as the "tunnel kiln" in which the brick are moved through a tunnel in which the heat is graduated has been in use to some extent in Europe, but has not yet been adopted by American producers.

cracks, a pail of mud is kept constantly on hand with which to smear the walls. The arches or fire places are generally unprotected except by a door which is removed when fuel is added. The top of the kiln is covered with one or two rows of burned or unburned brick called "flatting." Frequently the flatting courses are given little or no attention, there being no thought of controlling the heat by regulating the flues at the top. The ordinary scove kiln is shown in the accompanying plates. The permanent up draft kiln, on the other hand, usually has solid walls constructed out of burned brick. The kiln is usually open at one end so that the brick may be easily removed after being burned. The walls of the kiln are often two and one-half feet thick at the base tapering at the top to twelve or fourteen inches. The flatting of such a kiln usually consists of one or two layers of unburned brick or bats.

The permanent kiln is far preferable to the scove kiln and easily repays the owner for the additional cost of construction in the better and more uniformly burned brick. It is always more or less difficult to burn all the brick uniformly hard in a scove kiln. It frequently happens that the brick around the arches are almost melted while the brick near the sides and top of the kiln are underburned. The heat is radiated very rapidly from the scove kiln and can be maintained uniform only with the greatest difficulty. The heat is not only radiated from the top of the kiln but it also passes through the thin walls which are often broken with numerous small cracks. The walls are often so thin that a strong wind drives the heat from one or the other side of the kiln in such a manner as to almost cool the partially burned brick on the windward side. In a scove kiln, such as is commonly constructed, brick can only be successfully burned under the most favorable conditions. As it is there is always a greater or less quantity of underburned or soft brick which must be separated from those that are properly burned and sold at a discount.



SOFT MUD MACHINE.

The Down Draft Kilns.—There are two common types of down draft kilns, known as the round and square. The principle of the down draft kiln is different from that of the up draft in that the heat enters at the top and is carried down through the brick stacked in the kiln and out through one or more flues at the bottom which are connected with a chimney or chimneys on the exterior. The fire places are outside of the kiln and the flame is not supposed to reach the brick which are separated from it by a wall. It has been demonstrated that the fire can be more easily controlled and a much more uniform heat be maintained in a down draft than in an up draft kiln. The round down draft kiln is the commonest type and is illustrated in plate II. The square down draft kiln operates on the same principle as the round down draft, and is shown in plate III.

The Continuous Kiln.—The principle of the continuous kiln is somewhat different from that of either the round or square down draft. This kiln consists of chambers separated from one another by thin paper partitions. The brick are stacked in several of these chambers and the fire started in one end where suitable fire places have been constructed. After the fire is started fuel is fed into the kiln through small apertures at the top. The fire progresses from one part of the kiln to the other, creeping gradually ahead as the fuel is fed farther and farther in front. The chambers which are in front of where the fire is burning are filled with brick which receive the heat therefrom. In this manner the brick are dried sufficiently so that they can be burned without danger when the fire reaches the chamber in which they have been stacked. The chambers are constructed in two rows each of which is connected with the one in front of and behind it. The fire is never allowed to go out and there are sufficient chambers so that the brick may be burning in one, drying in another, and being taken out of a third at the same time.

The continuous kiln is supposed to be the most economical kiln yet constructed, although it requires careful attention and experience to burn and operate it successfully.

All of the kilns, with the exception of the continuous, may be so constructed that either wood or coal can be used for fuel. The down draft kilns, however, operate most successfully with coal. Petroleum and gas are used in some sections of the country although not very generally.

THE MANUFACTURE OF DRAIN TILE.

Drain tile are manufactured out of clay which has the same consistency as that used in the manufacture of stiff mud brick. For this purpose the clay requires careful pugging and mixing before being transferred to the machine. The tile are dried in sheds having two or three floors especially arranged to permit a ready circulation of the air. Some of the sheds are equipped with steam pipes for artificial drying, but most of them simply utilize the natural air for this purpose. Most of the drain tile are burned in down draft kilns although a number of the factories in Wisconsin burn the tile in the interior portion of up draft scove kilns.

THE USES OF SAND.

Sand such as is used for moulding is also one of the most important materials mixed with clay for the manufacture of brick. In some of the brick yards there is a tendency to add large quantities of sand to the clay as it is taken from the bank. This is not done because better brick can be manufactured thereby but because the clay can be worked easier and with less danger of loss in drying. There is much less danger of the brick cracking in the hacks or on the pallets and ordinarily less fuel is required to burn the brick when a considerable quantity of sand is mixed with the clay. The manufacturer, however, should not lose sight of the fact that it is his duty and to his interest to make the very best brick that he can from the clay at his disposal. It should never be his aim to lessen the cost of manufacturing and sacrifice thereby the quality.

The moulding sand is sometimes pure quartz but more often it contains varying percentages of calcite, dolomite, feldspar and iron oxide, all of which act as fluxes. In case the calcite and feldspar occur in considerable quantities, they often fuse with the quartz forming a glassy flux, on account of which the brick stick together in the kiln. This may cause endless difficulty when it comes to removing the brick from the kiln. Sometimes the brick adhere so tightly that they can only be separated by aid of a hammer. Those who are manufacturing brick in the region of the calcium clays should be especially careful to obtain sand which is free from lime, otherwise they may experience difficulty through the brick adhering to one another when burned in the kiln.

In case the quartz sand is stained with iron oxide it usually burns red or brown. When the iron oxide is absent or occurs in small grains the sand usually burns a white or gray color. In the manufacture of red brick it frequently happens that a white burning sand is used for moulding, on account of which the color of the brick is deadened. Occasionally where a brick has a natural dull red color a sand which burns a brilliant cherry red is used to enliven the color of the brick. Artificial coloring matter such as colorific is sometimes added to the sand for this purpose. Where red burning or artificially colored sand is used to brighten the red color of a brick it serves as a veneer which will disappear in a few years leaving the walls of the building the natural color of the brick.

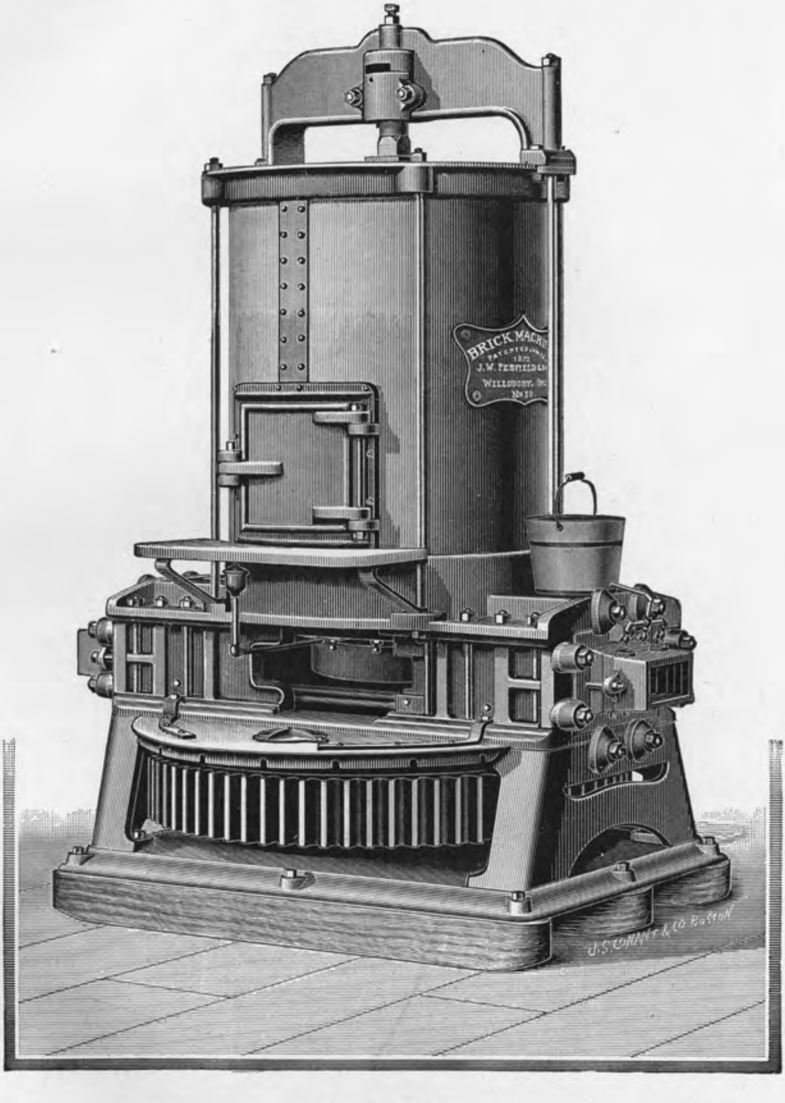
The sand which is used for moulding must be thoroughly dried before being used. Two or three different methods of drying sand are employed at the various yards in Wisconsin. A greater part of the sand is dried on ovens constructed for that purpose. Where scove kilns are used in burning, the sand is frequently banked against the walls of the kiln where it is dried by the heat which is radiated from the kiln. After it is dried it is removed to a shed and kept for future use.

GRADING OF BRICK.

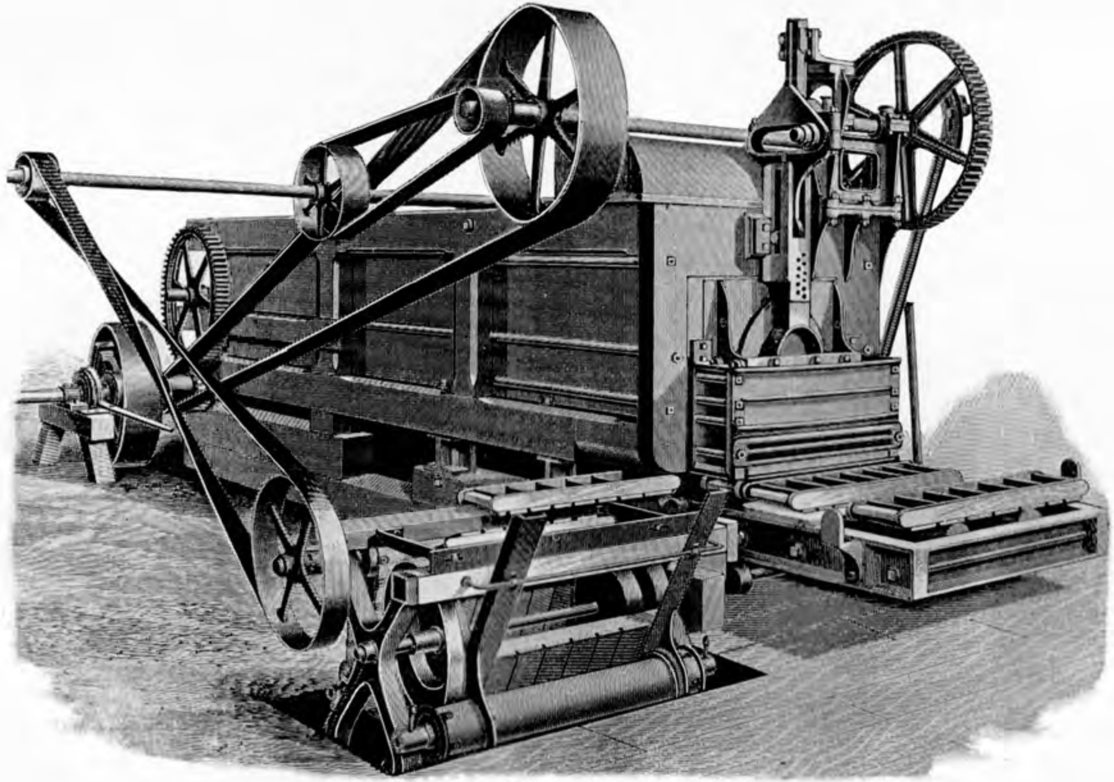
There is no recognized standard size for brick among Wisconsin manufacturers. The brick in this state differ in size not only at different yards, but even in a single kiln. The brick constituting the arches of a kiln are often very much smaller than those at the top owing to the great difference in the heat to which they have been subjected. The brick in one kiln are often burned harder than in another and consequently differ in size. Manufacturers frequently use the same size of mould for all clays without respect to their shrinkage values. In obtaining moulds, account is not always taken of the shrinkage of the clay, either in drying or burning. In the manufacture of common brick this may not be a serious objection, but brick which are used for fronts to buildings ought to be strictly uniform in size. They should also have perfectly smooth faces and square corners so that they can be laid with close joints. The standard size, adopted by the National Brick Manufacturer's Association, of a good, hard, common brick (burned) is $8\frac{1}{4}$ inches x 4 inches x $2\frac{1}{4}$ inches and that of a re-press front brick $8\frac{3}{8}$ inches x 4 inches x $2\frac{3}{8}$ inches. These sizes should be maintained by all manufacturers of common brick.

Many common soft and stiff mud brick are used for fronts to buildings. Where carefully selected they sometimes make a neat wall but more often it is ragged and unbecoming. The end cut stiff mud brick are especially poorly adapted to this use on account of their rough ends. For this reason, unless the brick are to be repressed, a side cut brick is preferable to one which is end cut.

Common brick are graded either according to the manner in which they are burned or the uses to which they are put. The different Wisconsin manufacturers distinguish mainly hard, soft, chimney, well, sidewalk, veneer, and select



STIFF MUD MACHINE.



SOFT MUD MACHINE AND MOULD SANDER.

brick. The grades which are made for common brick do not consider color and are seldom the same for yards located any considerable distance from one another. A great part of the brick are sold as they come from the kiln, without grading, and are known as "kiln run" brick.

The dry press or re-press brick are usually graded into two classes, commonly known as hard and soft. The soft brick are sold without further grading as common brick. The hard brick, on the other hand are often graded according to color into many classes.

For the best work, the public demands a perfect brick, with sharp square corners, and uniform in size and color. In order to maintain this standard the brick must be carefully sorted and graded before being placed on the market.

Vitrified or hard burned brick are at the present time being pushed into the market for building purposes. However, a building brick, as well as having strength and wearing qualities, should be a poor conductor of heat. For this reason vitrified brick should be less desirable than those that are burned to the ordinary hardness. The greater heat conductivity which a vitrified brick has over a well burned building brick is a serious objection to its use in buildings constructed in a northern climate. It is thought that the greater strength and durability of a vitrified brick hardly compensates for its greater heat conductivity.

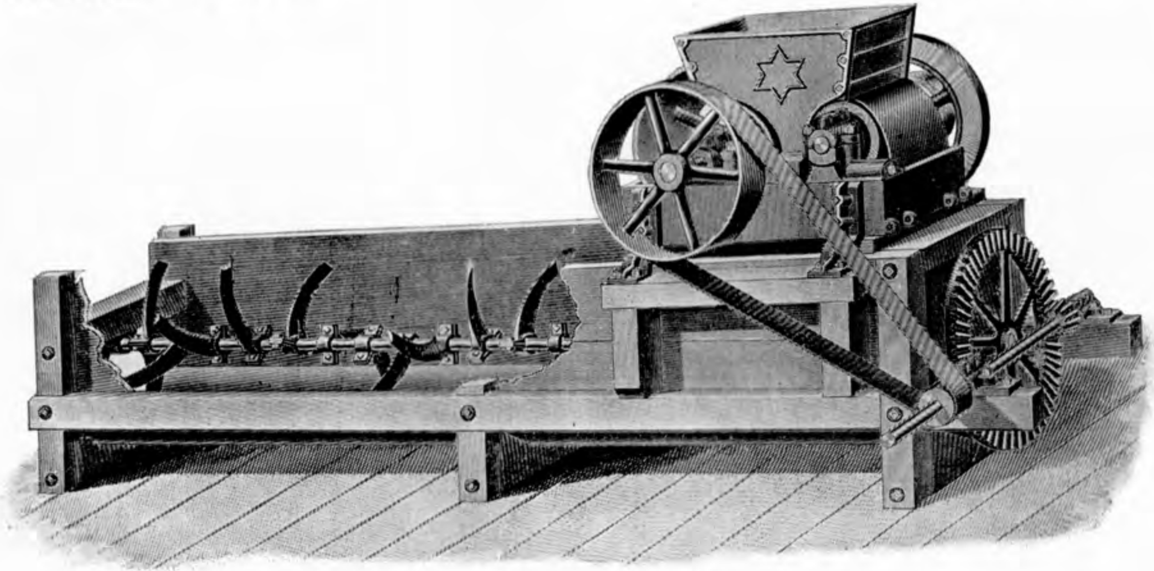
CHAPTER VII.

THE LACUSTRINE OR LAKE CLAYS.

The lacustrine clays which occur throughout the eastern part of the state adjacent to Lake Michigan and in the northern part of the state contiguous to Lake Superior are the richest sources of material for the manufacture of cream colored brick that are found anywhere in the north central part of the United States. These deposits were formed after the glacial period and during what are known as the interglacial epochs. These periods of time between the successive advances of the ice sheet are represented by a depressed condition of the land and a flooding of the river channels with quiet water. The lacustrine deposits were formed contemporaneously with the estuarine deposits to be discussed in the next chapter and have a maximum thickness along Lake Michigan of about one hundred and fifty feet. Along Lake Superior the deposits are reported to be very much thicker. They consist of layers of boulder clay, gravel, sand, and fine grained laminated clay. The clay outcrops in many places adjacent to the shore oftimes forming almost vertical cliffs. Rivers and small streams have cut trenches entirely or partly through the deposits exposing the clay in hundreds of places throughout the region adjacent to the Great Lakes.

At the surface the clay is frequently capped with a variable thickness of gravel, sand, or boulder clay. The clay itself often passes below into sand and sometimes into boulder clay.

The color of the clay varies from reddish brown or light purple to a grayish blue. It often consists of deep choco-



DISINTEGRATOR AND PUG MILL.

late brown or red brown layers which alternate with those having a bluish gray color, on account of which the clay is known as "chocolate cake" clay. Other portions of the clay have an almost uniform grayish blue color.

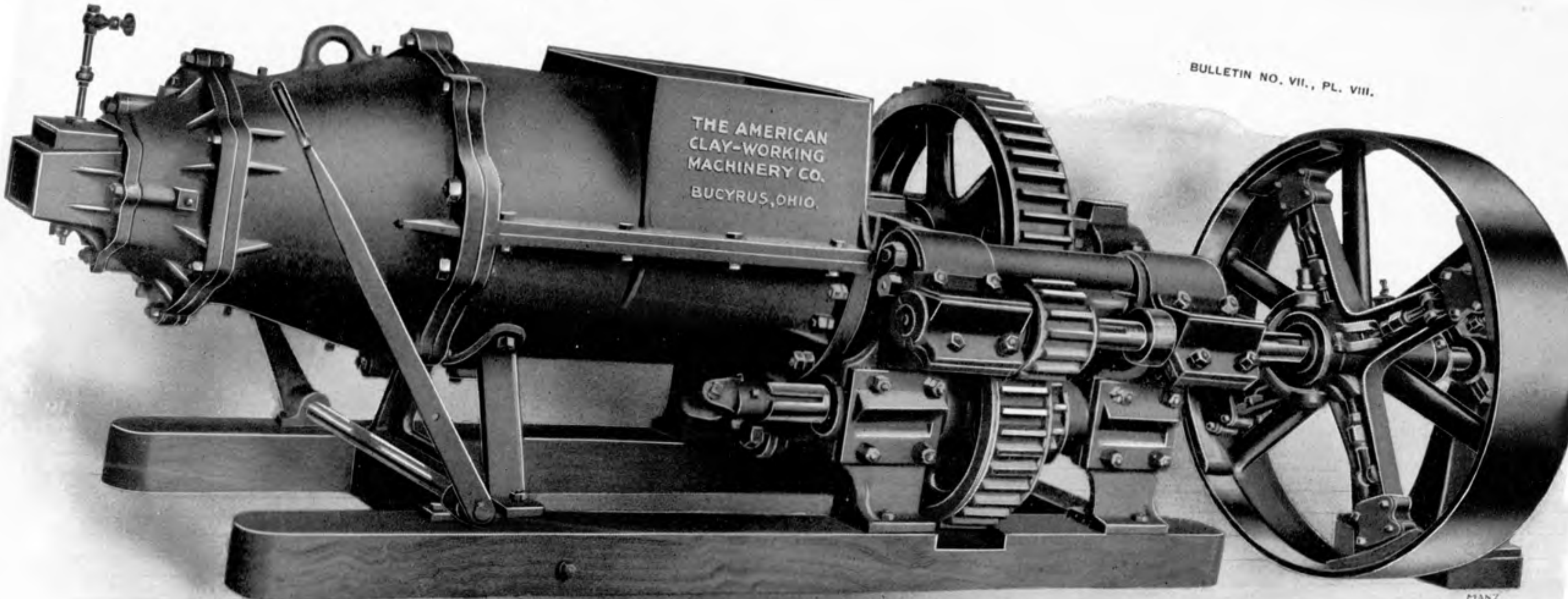
The laminae out of which the stratified portions are composed are separated from one another by a thin layer of coarse sand which constitutes an easy plane of parting. The chemical and mineralogical compositions of the clay from different parts of the lacustrine clay region are essentially the same. Quartz, calcite, dolomite, kaolin, and the other less abundant minerals occur somewhat differently associated in the different parts of the region but the average composition of the different banks is very much the same. The clay contains a high percentage of calcite or dolomite, moderate percentages of quartz and iron oxide, and a low percentage of kaolin. The clay which occurs at or near the surface is an exception to this rule inasmuch as it contains small amounts of calcium and magnesium and a relatively higher percentage of iron than that which occurs at a greater depth.

Wherever the bank has a thickness of forty or fifty feet the clay almost invariably contains pockets or beds of limestone gravel and layers of boulder clay. The gravel is not entirely limestone but consists also of granite and greenstone. These fragments of foreign rock which are included in the clay are evidence that portions of the deposits are of later age than at least a part of the glacial drift. The glacial deposits which sometimes occur above the clay give evidence, on the other hand, that the glaciers must have advanced beyond the lake clays after the latter had in part at least been deposited. This, combined with the position of the estuarine deposits which are commonly overlain by glacial deposits, leads to the assumption that the clays are not exclusively post-glacial but in part at least inter-glacial or pre-glacial. It is possible that the lower beds are inter-glacial while the upper deposits are post-glacial. The relation which these clay deposits bear to the successive advances of the ice sheet has never been worked out. The drainage of a large part of the region contiguous to the great lakes may have been so obstructed by the first advance of the ice sheet as to account for considerable accumulations of clay before the ice sheet covered the region. Each of the successive advances and retreats of the glacier may have been accompanied by depositions of clay which varied in thickness depending largely upon the rapidity of the advance and retreat of the ice sheet. Before any authoritative statement is made concerning the age and relation of these deposits a great amount of detailed field work must be done.

The materials composing the lacustrine clays were derived in a large part from the underlying limestone formations by disintegration which took place through stream and glacial erosion. The calcite and dolomite as well as the quartz, occur in grains as a part of the mechanical sediments.

For a depth of from one to three feet below the surface the clay contains much less calcium and magnesium, has a deep red color, and is higher in silica and alumina. This difference is attributable to the decomposition and removal of the calcite and dolomite by percolating waters, since the glacial epoch.

The lacustrine, as well as the estuarine deposits to be considered in a subsequent chapter, consist mainly of clay which burns a white or cream color. The only part of the clay which burns red is that which is contained in the upper one to five feet of the exposed banks. All the clay below this level burns to a white or cream color without respect to its color as it is taken from the bank. Much of the clay has a reddish color and analyses frequently give as much as four per cent. of the oxide of iron,—sufficient to color any ordinary clay a decided red. At an early day manufacturers were surprised to find that brick which were made out of this clay, when properly burned, had a white or cream color.



AUGER STIFF MUD MACHINE.

An explanation of this phenomena was offered by E. T. Sweet in a paper read before the Wisconsin Academy of Sciences, Arts, and Letters, in February, 1877. He suggested that there was probably a relation between the color and the high percentage of calcium and magnesium which are invariably present in the clay which burns to a cream color. Mr. Sweet further suggested that the iron, calcium, and magnesium undoubtedly entered into a combination very similar to certain members of the amphibole group, in which the iron does not appear as a coloring matter.

In the same report T. C. Chamberlin says, "At numerous points in the Lake region, and in the Fox river valley, cream colored brick are made from red clays. In nearly or quite all cases, whatever the original color of the clay, the brick are reddish when partly burned. The explanation seems to be that, at a comparatively moderate temperature, the iron constituent is deprived of its water and fully oxidized, and is, therefore, red, while it is only at a relatively high heat that the union with the lime and magnesia takes place, giving rise to the light color."[1]

From all the evidence that can be collected it is safe to conclude that the white or cream color of the brick of this region is not due to the absence of iron but to the presence of large quantities of calcium and magnesium carbonate which unite with the iron in such a manner as to obscure its color.

The individual deposits of this region will be considered in detail in the following pages.

ALGOMA.

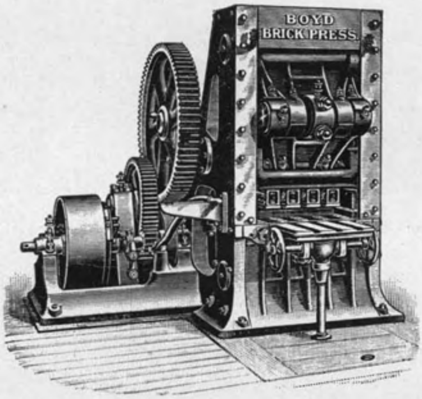
Algoma is in the northwestern part of Kewaunee County on Lake Michigan. The lake shore at this place is skirted with low banks of clay, a large part of which contains boulders and pebbles, forming a tough, resistant mass com-

[1] T. C. Chamberlin, Geology of Wisconsin, Vol. I, p. 669.

monly known as hard pan or boulder clay. The upper forty-six feet of the clay bank along the shore immediately north of the city is filled with pebbles and boulders. Underneath this occurs a bed of sand from five to six feet in thickness, interlaminated with which are thin streaks of clay. Below this occurs an unknown depth of clay which is free from pebbles. This clay is thinly laminated and appears as though it might be suitable for the manufacture of brick. The stripping, however, is so heavy that it almost precludes the possibility of working the bank with profit.

The only brick yard which is located in this vicinity is situated directly south of the city, near the outskirts, and is owned and operated by **Ferdinand Storm.** The upper three feet of the bank from which the clay is obtained contains numerous limestone pebbles, on account of which it is stripped. Underneath this gravelly clay there is a thickness of from three to ten feet of tough, red, apparently unlaminated clay, which is used for making brick. This clay should be thoroughly weathered before being soaked and tempered. A large portion of the clay from this part of the bank burns red. Underneath the red burning clay occurs five feet of thinly bedded, yellow burning clay, which is interlaminated with thin layers of sand. Underneath this occurs a thickness of from one to four feet of blue clay which burns white. Below this horizon is an unknown depth of clay which contains considerable fine gravel, on account of which it is unsuitable for the manufacture of brick.

In working this bank it is necessary to mix all the clay between the upper and lower boulder clay beds. There is sufficient sand in the middle layers, so that none need be added from outside sources. The brick resulting from this mixture have a white, cream, or yellowish green color, depending upon the temperature at which they are burned.



DRY PRESS MACHINE.

The clay contains a high percentage of calcium carbonate and is unsuitable for the manufacture of either vitrified or refractory wares.

The bank is worked by undermining the clay with pick and shovel. The clay is hauled to a vat in which it is mixed with water and allowed to soak over night. The brick are moulded in a "Reliable" machine which is operated with a hand lever. The brick are dried in hacks on the yard and burned in scove kilns. The facilities for protecting the brick from wind and rain while drying are very insufficient on account of which there is constant danger of loss. Wood is used for fuel in burning and a little over one-half of a cord is consumed for each thousand brick burned. It requires about eigth days to complete the burn.

The capacity of the brick machine now used is from ten to twelve thousand brick a day. The output is exclusively common brick. Three hundred thousand brick were made in 1896; 120,000 in 1897; 400,000 in 1898. Labor costs about $1.50 a day and wood can be obtained for $1.50 to $1.75 per cord. The market is entirely local.

APPLETON.

The clay which occurs in the vicinity of Appleton is a part of the great mass of lacustrine clays occuring throughout the region and of which the Fox River valley is a part. The alternating layers of the laminated parts of the banks each have a different color although the clay as a whole has a reddish brown tint near the surface and bluish or pinkish gray color at a depth of from six to ten feet.

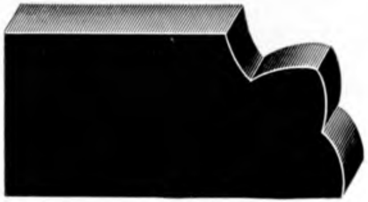
Two brick factories, known respectively as Carter's and Boetcher's brick yards, are located southwest of Appleton and about one and one-half miles from Appleton Junction, near the Chicago and Northwestern Railroad. The plants are located near each other and the clay which occurs at both yards is essentially the same.

The brick yard owned by **William Carter** is situated on the Chicago and Northwestern Railroad and is directly west of the yard owned by Henry Boetcher. The clay bank consists of a stripping of from one to one and a half feet of red burning clay. Underneath this occurs from two to four feet of clay interlaminated with thin layers of sand. Underneath the brown clay occurs from six to ten feet of pinkish colored clay which burns white; thirty to thirty-two feet of interlaminated blue and pink colored clay; and an unknown depth of sand and gravel. Of the lower thirty or thirty-two feet of "blue" clay only the upper six inches is being used. The brown clay which occurs near the top contains sufficient sand so that when it is mixed with the blue clay no additional sand is needed to make easy working. In certain parts of the bank hard nodules known as "clay dogs" occur in considerable numbers. The "clay dogs" in this bank are mainly fossil crinoids, which, on account of their calcareous composition injure the brick in the same manner as limestone pebbles. The only way to rid the clay of them is by screening, crushing, or grinding. In this place those portions of the bank which contain clay dogs are removed to the dump pile.

At this yard the clay is taken directly from the bank to the pug mill and tempered before being passed into the brick machine. The brick are made both by the stiff and soft mud processes. The stiff mud machine is a "Big Wonder" and is provided with an automatic end cut-off. The brick are carried away on double spring off-bearing trucks, dried in hacks on the yard, and burned in scove kilns.

The capacity of the dry yard is about 200,000 and the kiln capacity is about 1,400,000. It requires about seven days to burn the brick, and from thirty-five to forty cords of mixed wood, ash, oak, elm, and bass, are consumed for each one hundred thousand brick burned. Each of the machines, which are run by steam power, have a capacity of about 36,000 to 40,000 brick per day.

The brick made on the stiff mud machine were sold in 1899 at $5.50 per M and the sand moulded soft mud brick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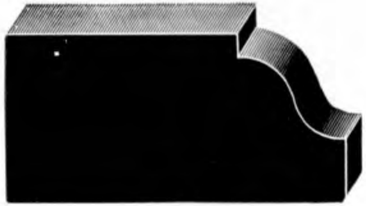
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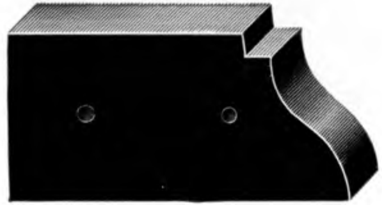
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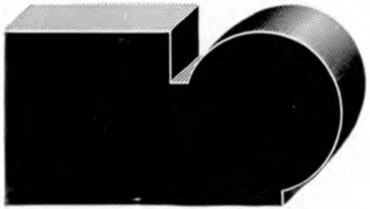
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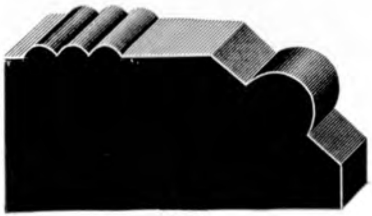
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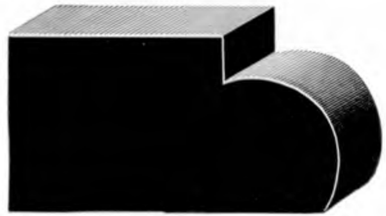
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SHAPES OF ORNAMENTAL BRICK.

brought $6.50. From fourteen to fifteen men are employed on the yard. The output in 1898 was 2,500,000; in 1899 it was something over 1,500,000. Mr. Carter has shown more than ordinary skill in constructing and managing his kilns so that the brick are burned uniformly hard. In setting the brick in the kilns care is taken to so arrange the flues that the heat will be uniformly distributed throughout the entire kiln. A simple device consisting of canvas strung in front of the are places has been employed to prevent the cold air from reaching the brick through the arches.

Henry Boetcher's Brick Yard is east of that owned by Carter and is about a fourth of a mile from the Chicago and Northwestern Railroad. The clay bank consists of three feet of tough, red clay at the top which is usually stripped and thrown back into the pit. Below the red clay occurs forty feet of what is known as blue clay. This, however, is only worked to the water level which occurs at a depth of about fifteen feet. To this depth the clay is very homogeneous but very indistinctly laminated. The remaining twenty-five feet which is below water level is strongly laminated.

The clay is shoveled from the bank into carts and transferred directly to a pug mill where it is tempered before passing into the brick machine. Both stiff and soft mud machines are used. The soft mud machine has a capacity of from 16,000 to 18,000 per day, while the stiff mud machine will turn out from 20,000 to 22,000. The stiff mud machine is provided with an automatic end cut-off, and the brick are carried away on double spring off-bearing trucks. The brick are dried in hacks on the yard and burned in scove kilns. The capacity of the dry yard is at present 200,000. The kiln sheds will accommodate about one million brick. The brick are burned about seven days and it is said to cost about eighty cents per thousand for burning with wood at $3.00 per cord. A large percentage of the brick have a cream color, although some are pink or red due to mixing an indefinite quantity of red burning clay with that which burns white. The red color is also sometimes due to underburning.

This yard was opened in 1895 and has been operated each year between May 1st and October 10th. The output in 1897 was 300,000 and in 1899 it was over 1,000,000. The brick sold in 1899 at a price ranging from $5.50 to $6.50 per thousand.

ASHLAND.

The clays in the vicinity of Ashland are tough and plastic and usually contain much limestone gravel. Throughout the entire region adjacent to Lake Superior there was only one brick yard in operation in 1899. This yard was located about two miles west of Ashland on the Northern Pacific Railway,[1] and was being operated by **Edward Hartmann.** The land on which the yard is located is owned by John Hockers. Mr. Hartmann commenced to manufacture brick at this place in 1888 and has operated the yard during the summer months of each year since that time.

The clay bank which is worked has a depth of from eight to ten feet. Some of the clay is smooth and reasonably free from gravel but most of it contains limestone pebbles in such quantity as to seriously interfere with the manufacture of good brick.

The clay is tempered in vats and the brick are moulded in a soft mud machine operated by horse power. The brick are dried in hacks on the yard and burned in scove kilns. The output of the yard during the last three years has averaged about 500,000. The market for the brick has been mainly in the cities located between Bayfield and Hurley. The brick sold in 1899 for about $5.50 per M.

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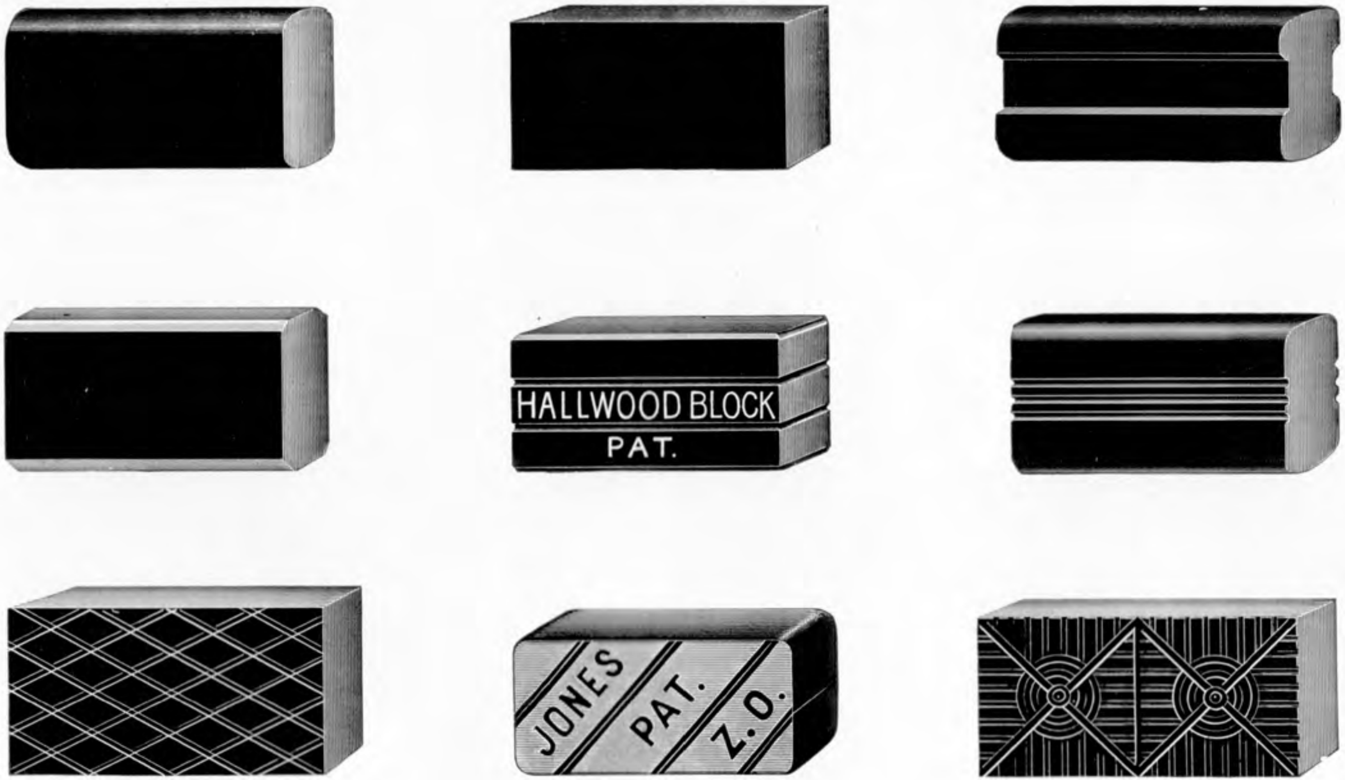
[1] Since writing this report the brick yard has been abandoned.



PAVING AND SIDEWALK BRICK.

The following analyses have been made of the red clays occurring in the Lake Superior region.[1]

Lacustrine Clay, Ashland.

Silica	58.09
Ferric oxide	4.44
Alumina	25.32
Calcic carbonate	4.31
Magnesic carbonate	4.01
Water	4.09
Total	100.26

Red Marly Clay, Lake Superior.

Ferric oxide	4.44
Alumina	25.32
Silica	58.09
Lime	2.41
Magnesia	1.91
Carbonic acid	4.00
Water	4.00
Total	100.26

Red Marly Clay, Lake Superior.

Ferric oxide	4.11
Alumina	18.86
Silica	64.56
Lime	3.58
Magnesia	1.70
Carbonic acid	4.65
Sulphuric acid	2.56
Total	100.02

Silicious Red Clay, Ashland.

Ferric oxide	4.11
Alumina	25.85
Silica	57.60
Lime	3.58
Magnesia	1.70
Carbonic acid	4.65
Sulphuric acid	2.57
Total	100.06

[1] Geology of Wisconsin, Vol. I, pp. 306-307. It must be understood that these analyses are of clays occurring near the surface and from which a large part of the calcium and magnesium have been leeched. Clays occurring deeper down show a very different percentage of calcium and magnesium.

BERLIN.

Berlin is located in the northern part of Green Lake County near the western border of the lacustrine clay region. The clay that occurs in this vicinity does not differ materially from that which is found in other parts of the lake region.

The **Berlin Brick Yard,** which is owned and operated by *C. S. Morris,* was opened in 1885 and has been worked during the summer of each year since that time. The clay bank is located in the southwestern part of the city and has a thickness of about sixteen feet, the upper two feet of which is stripping. Underneath the clay occurs a bed of gravel. Near the middle of the bank the clay appears to be well stratified, while at the top and bottom the laminae are very imperfectly developed. The clay contains an occasional limestone pebble but apparently they are not sufficiently abundant to injure materially the brick manufactured therefrom. The clay at the bottom of the bank is finer grained and richer than that which occurs at the top. The top clay burns a reddish color while that underneath burns white or buff.

The clay is taken from the bank and removed to a large vat adjacent to the brick machine where it is soaked over night. It is then transferred to a Brewer brick and tile machine, pugged, and manufactured into stiff mud brick. The machine is run by steam power and is operated at a rate of 15,000 brick a day. The brick are moved on trucks and dried in hacks on the yard. The yard is provided with an abundance of canvas and saddle covers which are placed over the brick whenever there is danger from rain or wind. The brick are burned in scove kilns having a total capacity of about one million. Many of the brick near the kiln walls and around the arches are cracked in burning. This is due to the cold air striking the brick when they are hot. It was also observed that a considerable number of the brick were cracked through the center, which is probably due to the clay passing unevenly through the die of the machine. When one side moves faster than the other, fine cracks are very liable to be produced. The brick are burned about eight and one-half days and it costs in the neighborhood of 87 cents per M. for burning. The best quality of split and seasoned tamarack wood is used for firing and it gives excellent satisfaction.

The brick near the top and around the sides of the kiln have a pinkish color which is probably due to underburning, although as previously noted, it may be due in part to a mixture of the red and white burning clays. Whenever the red burning clay is mixed with that which burns a white or cream color the tendency is to produce a pink or very delicate shade of red.

This plant employs fifteen men, paying wages ranging from $1.00 to $1.75 per day. The markets for the brick are mainly Berlin, Ripon, Omro, Wautoma, and Green Lake. During the last three years the output of the yard has averaged about 700,000 brick, which sold in 1899 for $5.00 per M. kiln run.

The clay is very calcareous and unsuitable for the manufacture of vitrified or refractory wares. In the manufacture of brick care should be exercised to see that all of the limestone pebbles are removed before the clay is moulded.

BOLTONVILLE.

Boltonville is situated in the northeastern part of Washington County near the western limit of the Lacustrine Clay region, as shown on the map. One brick yard is located at this place.

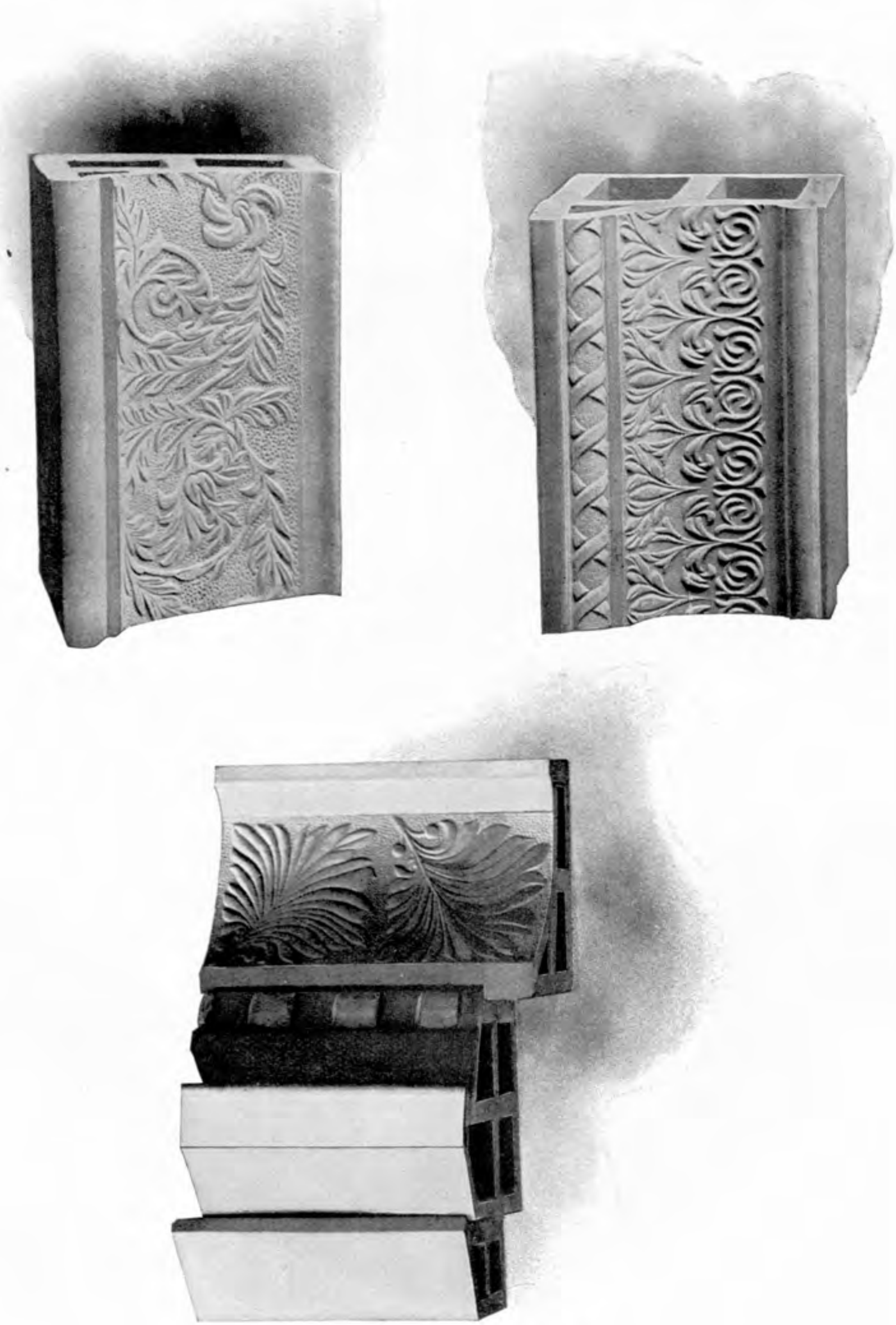
The **Boltonville Brick Yard,** which is owned and operated by *William Voigt,* was opened in 1884 and has been operated each year since that time from May 1st to November 1st. Soft mud, sand moulded brick are manufactured.

The clay bank which is worked has a thickness of from eight to twelve feet, although well borings in this vicinity show that the total thickness is 85 feet. Below this depth occurs an unknown thickness of sand. The surface clay to a depth of two and a half feet contains numerous limestone pebbles, on account of which it is stripped. Underneath this bed the clay is worked to a depth of from six to ten feet. The upper six feet has a reddish color and shows little or no lamination. The clay underneath this has a pinkish or bluish tint and is known as the blue clay. An occasional limestone pebble is found in different parts of the bank. The bank slopes at a moderate angle and is worked by plowing. After plowing the clay is dried and mixed with sand, about twenty loads being used for each 100,000 brick. The clay is then soaked in vats for two days after which it is passed into an Anderson soft mud machine in which the brick are made. The machine is mounted on trucks so that it can be moved on a track from one clay vat to the other. It is operated by horse power. The capacity of the machine is about 14,000 brick per day. The brick are dried in hacks and burned in scove kilns. It requires twelve days to burn the brick and about one-half cord of soft wood is consumed for each thousand brick burned. The capacity of the dry yard is about 40,000 and the kiln capacity is about 580,000.

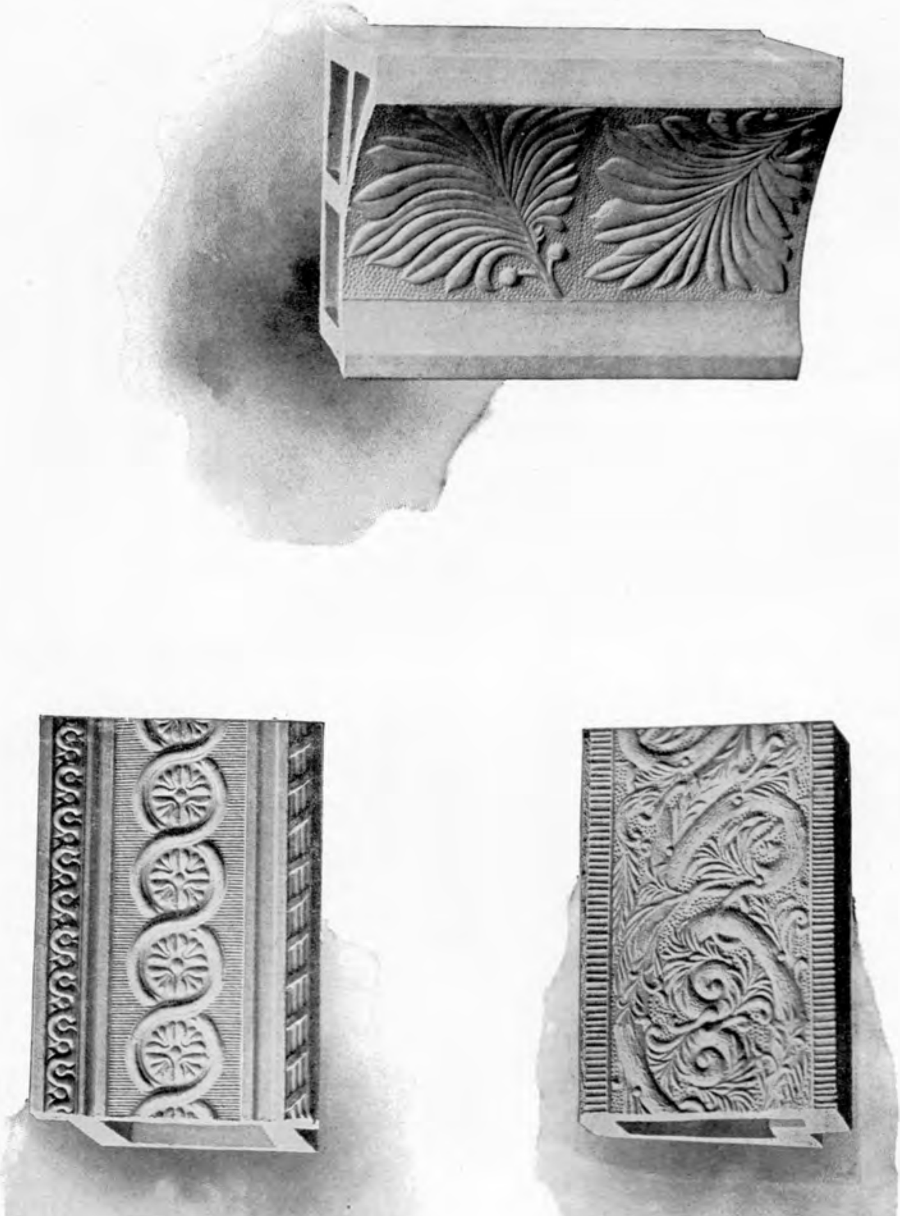
Six men are employed on the yard and they are paid an average of $1.25 a day. The average output of the yard during the last three years has been 430,000 brick, all of which were sold in the vicinity of Boltonville and West Bend.

Laboratory Examination.— Both the red and blue clays from this yard were examined in the laboratory of the Survey. The red clay was reasonably hard when dry and soft and plastic when wet. It has no distinguishing odor or taste. It is smooth and fine grained with little evidence of sand when tested between the teeth.

When rubbed between the fingers the clay has a peculiar smoothness which is characteristic of very fine calcareous clay. It is not the greasy feel which is so characteristic of plastic kaolin.



TERRA COTTA MOULDINGS.



TERRA COTTA MOULDINGS.

The color of the dry clay is pinkish or yellowish gray while the wet clay has a decidedly reddish tint. The clay slacks readily, breaking down into scales of moderate size.

The microscopic examination shows that this is among the finest grained of any of the lake clays examined. Only an occasional grain having a diameter as great as .03 of a millimeter was noticed. A few of the individuals were .011 of a mm. in diameter, many more were .003 of a mm., and multitudes were less than .0006 of a mm. in diameter. Probably a fair average of the diameter of the grains in this sample would be .0014 of a mm. Among the somewhat rounded grains were observed occasional elongated tabular crystals which were taken to be calcite or dolomite. Most of the grains, however, were irregular both in shape and size.

It is almost a hopeless task to attempt to identify the minerals which exist in particles as fine as those in this clay. The brown staining was thought to be due to iron oxide and a number of crystals of calcite were recognized by their rhombic outlines and high interference colors.

The blue clay taken from the same bank was hard and brittle when dry but smooth and plastic when wet. It has no distinguishing taste or odor but a fine gritty feeling was detected when the clay was tested between the teeth. Between the fingers the clay has the same smooth feeling which characterizes the red clay above described.

The color of the clay is gray with a faint buff tint when dry. When powdered it is almost white. When wet the yellowish tint observed in the dry sample is very much intensified. The clay slacks quickly, breaking down into a pulverulent mass, consisting of fine flakes.

The microscopic examination shows the clay to consist of grains which range in size from .066 to .001 of a mm. in diameter. Very few of the grains have a diameter of .066 of a mm., the average being about .0059. It will be noticed that the average grains in this sample are somewhat larger than those of the preceding. Rhombohedral crystals of calcite were easily identified and long prismatic forms thought to be dolomite were quite abundant. The percentage of the different minerals could not be determined, although calcite and dolomite were observed to be important constituents. A tendency for the very fine individual particles to cluster together in irregular masses was noted in this and other samples.

The sand which is used in moulding the brick was also examined microscopically. The black specks which can be seen with the naked eye were determined, under a moderately high powered lens, to be iron oxide. The other grains are of various sizes and have sharp angular outlines. Rhombic crystals of calcite are an abundant constituent of the sand, although quartz is the most abundant. The largest quartz individuals have a diameter of .5 of a mm. Many of the grains are .25 of a mm. in diameter, others are less than .01 of a mm., but the average is about .05 of a mm.

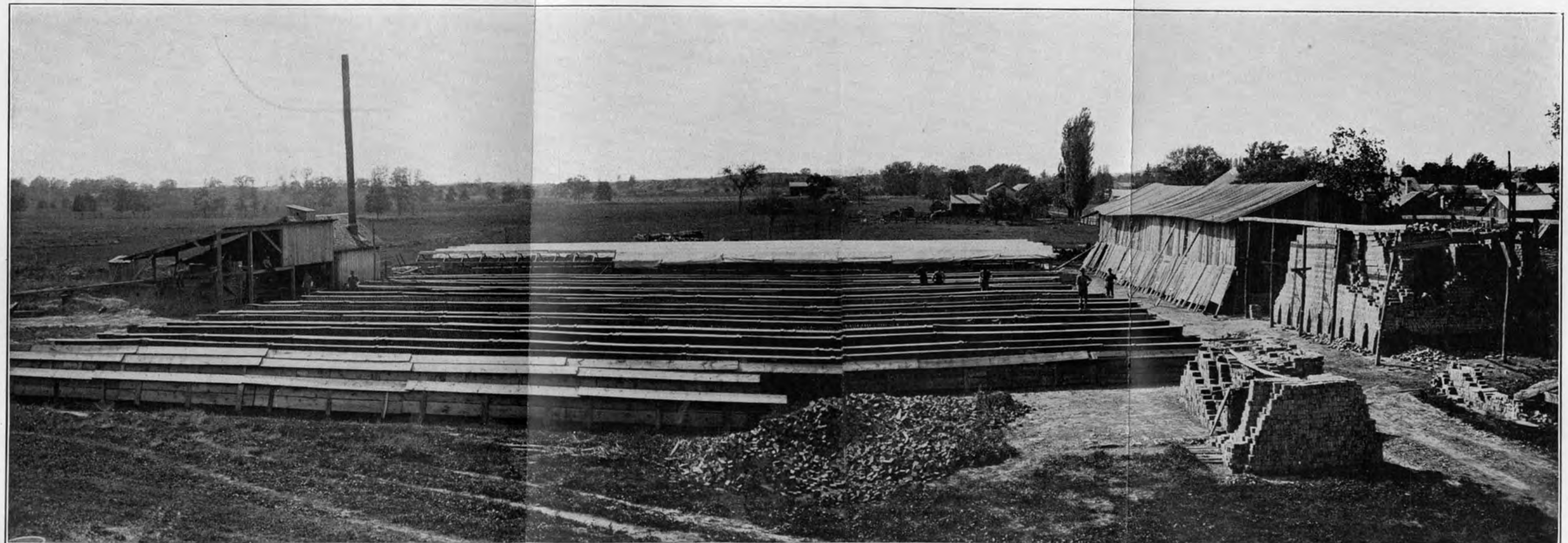
The heterogeneous size of the grains, their sharp and angular outlines, and the abundance of calcite account for the brick sticking together in the kiln, as pointed out by Mr. Voigt. In order to prevent the brick from fusing together it will be necessary to obtain sand from another locality in which there is less calcite and in which the grains are less angular.

The chemical composition of the clays from this yard will be found in Table I.

BRISTOL.

Bristol is located in the central part of Kenosha County on the Chicago and Northwestern Railway and near the western margin of the lacustrine clay region. One plant is located at this place which is known as the Bristol Brick and Tile Works.

The Bristol Brick and Tile Works, owned by *H. A. Nelson,* were opened in 1895 and have been operated from



BERLIN BRICK YARD, BERLIN.

April to November of each year since that date. Drain tile and common brick are manufactured, the former being the more important part of the business.

The clay bank which is being worked comprises a small hill or mound which has an elevation of about forty feet. The clay is covered in some places with a layer of gravel from one to two feet in thickness. This, with the soil or loam at the surface, are stripped and carried away. Underneath the sod and gravel occur two feet of reddish brown clay which burns red, and twelve feet of so-called blue clay which burns white. This blue clay is worked to a depth of six feet. Between the red and blue clays there is a layer of sand, six or eight inches in thickness. This sand is mixed with the clay used for the manufacture of brick, but is separated from the clay used for manufacturing drain tile.

The bank has a moderate slope and the clay is plowed and partly dried before being conveyed to the factory. By thus disintegrating the clay it soaks much more readily in the vat, where it remains from twenty-four to thirty-six hours.

An occasional limestone pebble occurs in the clay, on account of which it is passed through a Potts disintegrator and a Brewer crusher after being tempered. A No. 9 A Brewer machine is used for manufacturing both the brick and tile. Drain tile of all sizes from 2½ to 12 inches are manufactured. The machine is run by a thirty horse power engine, and has a capacity of 12,000 2½ inch tile, or 10,000 brick per day. The brick and tile are all dried under sheds, which can be opened on all sides to allow a free circulation of the air. Live and exhaust steam are used for drying when the weather is unfavorable. The brick and tile are burned in two kilns; one a square and the other a round down draft. The round kiln has a capacity of about 26,000 2½ inch tile. Coal and wood are both used for fuel.

The loss in drying is not over one per cent while the loss in burning is usually less than two per cent. The greatest loss in burning arises from setting the tile in the kilns before they are thoroughly dried. The tile manufactured out of the white burning clay shrinks about one inch in twelve in burning, while the red clay shrinks one and one-fourth inches in twelve. The less shrinkage of the white burning clay is due to the greater percentage of lime which it contains.

When the limestone gravel is not removed from the clay, the tile and brick manufactured therefrom usually chip and flake through the slacking of the lime when moistened. The greatest care should be exercised in removing the limestone pebbles either by crushing or otherwise before the clay is used. Limestone is changed into quick lime when the brick are burned and this is sure to slack after being exposed to the atmosphere. The expansion which always results from slacking lime will invariably injure the brick or tile. The tile and brick that are free from limestone pebbles are of good quality.

Laboratory Examination.— The red and blue clays were each examined in the laboratory both macrascopically and microscopically. The red burning clay is moderately hard and brittle when dry, and soft and plastic when wet. It has no distinguishing taste or odor. The presence of sand grains is evidenced by the gritting between the teeth. The color of the clay is pinkish gray when dry and yellowish brown when wet. It slacks moderately fast, breaking down into rather coarse scales or granules.

The largest grains observed were quartz which had a diameter of about .067 mm. However, the clay consists mainly of very fine grains most of which are less than .003 of a mm. in diameter. The average grains probably have a diameter of about .0059 mm.

Besides the iron oxide which stains the grains, quartz is the only mineral that can be positively identified. The smaller grains are very irregular in shape.

The blue clay is moderately hard and coherent when dry but is soft and plastic when wet. Occasional grains of sand sufficiently large to be detected between the teeth occur in this clay. It slacks readily breaking down into a flaky mass. When dry the clay has a pinkish gray color which is intensified upon wetting.

The largest grains have a diameter of .067 of a mm. From this size they range down to those which are less than .0059 of a mm. in diameter. About one-fourth of the clay mass is made up of grains having diameters of less than .0059 of a mm. The grains have a dirty, yellowish brown color, which is imparted by stainings of iron oxide. The outlines of the larger grains are comparatively regular, while the smaller ones are decidedly angular. It is exceedingly difficult to identify the individuals.

CHAMPION.

Champion is a small village located in Brown County, near the southeastern extremity of Green Bay. The clay occurring at this place is a part of the lacustrine deposit.

The Champion Brick Works are located in the N. W. ¼ of the N. E. ¼ of Section 10, Town 24, Range 22 E., and are owned by *Lambert Ansloos*. The plant is now operated by Ansloos' Sons. The manufacture of brick was begun in the spring of 1889 and has continued during the months of May, June and July of each year since with the exception of 1897. The brick are moulded by hand and dried in hacks on the yard. They are sold mainly in Green Bay, Benderville, Brooksburg, and adjacent localities. During the last three years the average annual output of the yard has been 200,000 common brick. The average price of the brick in 1899 was about $5.00 per M. kiln run.

CHILTON.

Chilton is located in the south central part of Calumet County, and is in the lacustrine clay region.

The Chilton Brick and Tile Works are located one-half mile south of the town and are owned and operated by *Fred Carter.* The clay occurs in the valley of the Manitowoc river and is obtained from a pit which has been dug from the surface. At the top for a depth of about two feet the clay contains gravel on account of which it is stripped. Underneath this occurs two feet of apparently unstratified red clay, four feet of thinly laminated yellow clay, and twenty feet or more of blue clay which is somewhat altered at the top and changes below from a blue to almost a black at the bottom. The lower twenty feet of the bank is apparently free from limestone gravel. The clay is hauled up an incline from the pit and passed through a crusher into a vat in which it soaks over night.

From the vat it is shoveled into a stiff mud machine having an end cut off. The brick and tile are dried on pallets under sheds and burned in round, down draft kilns. The dry sheds have a capacity of about 70,000 brick and the kiln capacity is about 65,000. The brick have a pinkish white color, due to mixing the red and white burning clays.

This company has experimented in the manufacture of hollow tile, square sidewalk brick, and vitrified paving brick, besides making drain tile and building brick. The experience in the manufacture of paving brick gave evidence that the clay would not stand up under the heat necessary to vitrify. Many of the brick in the kiln were melted. It is believed that this clay is too calcerous to be suitable for the manufacture of vitrified ware. It would be a difficult matter to burn an entire kiln without either under or overburning a great part of it. Sidewalk brick as well as paving brick should be vitrified and for this reason the clay is not suitable for their manufacture. The hollow building blocks, drain tile, and building brick which were examined had a very good appearance and for these purposes the clay can be used to good advantage.

This yard has been operated from May 15th to October 1st for about sixteen years. The output is very irregular. Common brick were sold in 1899 for $7.50 per M. The hard brick brought $8.00.

CLINTONVILLE.

Clintonville is located in the northeastern part of Waupaca County on the western border of the Lacustrine Clay area.

The Clintonville Brick Yard is located about one and a half miles north of the city. The clay is obtained from pits which have been sunk from the level ground. The clay has a reddish color near the surface and a bluish tint deeper within the bank. The clay is laminated and is said to be richest near the top. Between the laminæ of clay occur very thin layers of sand. The upper five feet burns red and that below burns a white or cream color. The clay has a thickness of twenty-eight feet in this vicinity as determined by well borings. Below this depth occurs quick sand.

When examined during the summer of 1899, the excavations were filled with water from numerous artesian wells which have been sunk at this place. The clay east of the brick yard is covered with thin patches of sand. In some places in this vicinity it is reported that clay cannot be found at any depth.

This brick yard was opened twelve years ago. It is equipped with "Quaker" soft mud and "Sword" machines. The clay is mixed on a board platform and transferred by means of a belt conveyor to the Quaker machine in which the brick are now moulded. The yard is equipped with pallet sheds having a capacity of about 70,000 brick. The brick are burned in a scove kiln. The color of the brick is red. The clay is calcareous and unsuitable for the manufacture of vitrified or refractory wares.

DE PERE.

See Green Bay.

DUCK CREEK.

Duck Creek is located in the south central part of Brown County a short distance north of Green Bay. The lacustrine clays in this part of the state have their greatest thickness in this vicinity. The deposits of clay consist of two parts, an upper weathered portion which burns red, and a lower unweathered portion, known as the blue which burns a white or cream color. Two brick yards are located in the vicinity of Duck Creek, one of which is operated by the Green Bay Brick Company and the other by the Duck Creek Brick Company.

The Green Bay Brick Company is located one mile south of Duck Creek and near the east bank of Duck Creek. Above the clay at this place is a thickness of from one to three feet of sand. Underneath the sand occurs seven feet of red clay, four feet of thinly laminated mixed red and blue clay, and five feet of thinly laminated blue clay. The top of the clay bank is 24 feet above the river and the clay can be mined to this depth without the necessity of pumping. In one part of the yard, back from the river, there occurs three feet of red burning clay at the surface. This clay is not used at the present time.

In some parts of the bank crinoid fossils, known as "clay dogs", are quite abundant. These fossils are as harmful as limestone gravel and if not separated from the clay they will burst the brick after they are removed from the kiln. With the exception of the "clay dogs" the bank is remarkably free from injurious constituents of any kind.

The clay is moved from the bank to the mill on cars operated with a cable and revolving drum. It is passed through a disintegrator and from there directly into the pug mill connected with a Potts soft mud machine in which the brick are moulded. The capacity of the machine, as operated, is about 31,000 a day. The brick are dried on pallets under sheds and burned in scove kilns. The capacity of the pallet sheds is from 350,000 to 400,000. The total kiln capacity is 250,000. It requires eight to nine days to burn the brick and about one-half cord of wood per thousand is consumed in burning. The brick have a cream color when properly burned.

A spur track connects this yard with the Chicago, Milwaukee and St. Paul railroad. The brick are shipped mainly into northern Michigan.

In the fall of 1899 the company lost 100,000 brick by frost. This illustrates the danger which threatens every yard which has no means of protecting the brick with artificial heat while drying.

Laboratory Examination.—The red burning clay is moderately hard when dry but soft and plastic when wet. It feels smooth when dry but has no distinctive odor or taste.

When examined closely it is found that the clay consists of alternating reddish brown and yellowish gray layers, which give it the general appearance of "chocolate cake," from which it is called chocolate cake clay. The composition of the layers is quite different.

The reddish brown layers are tough and plastic and the others are short and sandy. The clay as a whole might be said to consist of layers of clay separated from each other by thin seams of argillaceous sand. The clay layers slack moderately fast, breaking down into large concentric flakes, some of which are so thin that they will float on the surface of the water. Under the microscope the individual grains are seen to cluster together, apparently loosely cemented with the iron oxide which occurs in considerable quantity as a staining agent. The individual grains are very small, the largest observed not exceeding .014 of a mm. in diameter. A greater part of the clay consists of grains of which the diameter is less than .0059 of a mm. Many of the grains have diameters of less than .001 of a mm. The smallest grains appear simply as dots in the field under a lens which magnifies 720 diameters. Many of the smaller grains are distinctly unequi-dimensional in size. A number of tabular crystals having rhombic outlines, presumably calcite, were observed. The percentage of the different mineral constituents could not be determined. The thin layers interlaminated with the clay are largely composed of quartz grains much larger in size than those of the clay.

The examination of the fine grained clays under the microscope usually reveals two layers of grains floating between the cover and object glasses. The grains of one of these layers usually cling to the cover glass and those of the other layer adhere to the object glass. When the water between the two glasses is stirred the two layers move over one another, sometimes apparently without interference.

The white burning clay is hard and brittle when dry and soft and plastic when wet. It consists of alternating layers of chocolate brown and yellowish gray layers from a fraction of an inch to five inches in thickness. The clay layers consist of grains which are somewhat coarser than those of the red burning clay. However, many of the grains are less than .001 mm. in diameter. The buff or gray tinted layers contain a considerable quantity of coarse quartz grains. Numerous rhombs of calcite were observed among the mass of irregular shaped grains.

The works of **The Duck Creek Brick Company** are located about half a mile from the Green Bay Brick Company's yard and on the opposite side of the river. The Duck Creek yard is owned and operated by *C. Crevcoure*, *J. A. Lamoye*, *C. M. Skeeno*. The plant was opened in 1895 and has been operated from May to September of each year since. Soft mud, sand moulded brick are manufactured exclusively.

The clay bank is covered with one and one-half to six feet of sand and gravel which is stripped. Underneath this occurs one and one-half feet of red burning clay, one and one-half to three feet of interlaminated red clay and sand which burns a yellowish red color, and eight feet of thinly laminated blue clay which burns a white or cream color. An occasional limestone pebble occurs throughout the bank.

The clay is hauled on a dump wagon from the bank to the factory. Here it is passed through a crusher and from thence on a belt conveyor to a Henry Martin soft mud machine in which the clay is pugged and the brick moulded. This machine has a capacity of 24,000 brick a day. The power is furnished by an engine of 20 h. p. capacity.

The brick are dried on pallets under sheds and in hacks on the yard. They are burned in scove kilns having a total capacity of about one million brick. It requires from nine to ten days to burn the brick and about one-half cord of mixed soft wood is consumed for each thousand brick burned.

On account of the severe frost in the fall of 1899, the company lost 40,000 brick which were drying on the yard. This is another example of the danger attendant upon drying brick without artificial heat.

The brick from this yard are sold mainly in Green Bay, Oconto, Marinette, Seymour, and Clintonville, Wisconsin, and Menomonie, Ishpeming, Escanaba, and Iron Mountain, Michigan. During the last three years the average annual output of the yard has been one and one-fourth million.

Laboratory Examination. —The red burning clay is moderately soft when dry and fairly plastic when wet. It has no distinguishing odor or taste but feels somewhat sandy. The clay has the "chocolate cake" appearance noted in that from the previously described yard. It consists of alternating dark reddish brown and yellowish colored layers. It slacks readily, breaking down into a loose, fluccolent mass in which the scales are somewhat coarse.

The largest grains observed under the microscope had a diameter of from .2 to .17 mm. It was estimated that about three-fourths of the clay consists of grains that are .014 mm. or over in diameter. None of the grains appear to be equi-dimensional in size. They were very irregular and angular in outline. This was especially true of the quartz grains. Several rhombs of calcite and prismatic individuals of dolomite were recognized. The entire mass of clay was quite uniformly stained with iron oxide.

The clay which burns a mixed red and white is harder than the preceding when dry but very soft and plastic when wet. It resembles in color that which occurs immediately above except that it is a little lighter. The clay slacks readily, breaking down into moderately fine scales, somewhat smaller than those of the preceding sample.

Microscopically, the clay is very much the same as the preceding with the exception that the large grains are not so abundant. The largest grains observed had diameters of about .1 of a mm., although the major portion of the clay consists of grains having diameters of less than .0058 mm. This sample is not so thoroughly impregnated with stainings of iron oxide as the preceding. Quartz, calcite, dolomite, and kaolin grains make up the mass of clay. The calcite and dolomite appear to be present in considerable quantities as evidenced by the number of rhombic sections seen under the microscope.

The white burning clay consists of alternating layers of reddish brown and grayish blue clay which give the "chocolate cake" appearance previously described. It has no distinguishing odor or taste, feels smooth between the fingers when dry, and is plastic when wet. It slacks readily, breaking down into a fine, pulverulent, scaly mass.

Under the microscope the individuals of the light colored layers were observed to be angular in shape, the smaller grains being the more irregular. Rhombs and prisms of calcite are moderately plentiful.

The largest grains observed had diameters not exceeding .014 mm. and the mass of the clay, consists of grains not having diameters of over .0058 mm. Many of the grains were too small for identification, being under .001 mm. in diameter. The light colored layers are very quartzose, having a relatively small percentage of kaolin base.

The clay which occurs at both yards is very calcareous and unsuitable for the manufacture of either refractory or vitrified wares. The clay is admirably adapted to the manufacture of brick, drain tile, earthenware, and such other wares as do not require vitrification.

MISHICOTT.

Mishicott is situated about five miles northwest of Two Rivers, Manitowoc County, and is in the midst of the lacustrine clay area.

Shaff's Brick Yard, which is located on the west bank of the East Twin River near this place was opened in 1878 and has been operated each year since that time from May to October. The upper ten to twelve feet of the bank which is being worked consists of interlaminated sand and clay. Underneath this mixture occurs seven feet of quick sand and an indefinite thickness of clay, twelve feet of which is above the level of the river. At the present time only that part of the bank which is above the quick sand is being worked. The clay is first plowed and allowed to weather after which it is soaked in vats for twelve hours. The clay is mixed in wooden pug mills operated by horse power. The brick are moulded by hand, dried in hacks on the yard, and burned in scove kilns. It requires about ten days to burn the brick and about one cord of mixed pine and ash wood is consumed for each thousand brick burned. The capacity of the dry yard is 10,000 and that of the kilns 600,000. Nine men are employed in the yard. The average annual output during the last three years has been between 400,000 and 500,000 brick.

The brick are not as strong as many that are made in this region, due probably to the large percentage of sand which is mixed with the clay. The brick would be much stronger if the clay from underneath the quicksand were mixed with that above. The output from this yard is sold almost exclusively in the vicinity of Two Rivers.

FOND DU LAC.

Fond du Lac is situated in Fond du Lac county near the south end of Lake Winnebago. The only brick yard at this place is situated in the south end of the city and is owned and operated by **Herman Hass.** The bank from which the clay is obtained is worked to a depth of about three to three and one-half feet. The clay has a much greater depth but contains so much limestone gravel below this level that it cannot be used to advantage. The clay which is now used, contains many small shells besides limestone gravel both of which impair the quality of the brick.

The clay is soaked in a vat over night and afterwards mixed in a wooden pug mill operated by horse power. The brick are moulded by hand in steel lined moulds and are of the slop brick type. The brick are dried in hacks on the yard and burned in scove kilns. Many of the brick which were being dried on the yard at the time the plant was inspected were badly cracked on the side exposed to the direct rays of the sun. This is a common danger attendent upon drying brick in the air without protection. During the fall of 1899 30 per cent of the brick were lost in drying and 50 per cent were lost in making. These losses were largely due to the method of manufacture, which does not provide protection for the brick during seasons of rain or frost.

FORESTVILLE.

The Forestville Brick Yard is located in Door County on the Ahnapee & Western Railway about six miles south of Sturgeon Bay. The valley through which the Ahnapee river flows was probably at one time filled with clay similar to that which occurs along the lake shore at Algoma and Kewaunee. At the present time only remnants of these clay deposts remain in the new valleys which have been carved by the rivers.

The clay bank at this particular locality consists of from two to five feet of red, gravelly clay at the surface underneath which occurs six feet of laminated red clay, interstratified with thin layers of quick sand, and about twenty-five feet of blue clay.

The upper layers of red clay burn red and the remainder including the blue burns a cream color. When the clay from the bank is mixed indiscriminately it usually burns either a light red or a mottled pink and white color.

This clay bank is owned by *Edwin Decker* of Sturgeon Bay and the plant is operated by *F. Rose.* The yard was opened in May, 1895, and has been operated from May to August of each year since that time with the exception of 1897.

After removing the clay from the bank it is mixed in a wooden pug mill operated by horse power. The brick are moulded in an "Old Reliable" hand press machine, the output of which is from 10,000 to 12,000 brick per day. The brick are dried on board pallets under sheds and burned in scove kilns. Wood is used as fuel and it requires about eight days to burn a kiln. The output of the plant in 1898 was about 180,000 brick, all of which were sold to farmers residing in the vicinity of Forestville.

The clay occurs at this place in large quantities, is close to the railroad track, and apparently free from limestone gravel. The clay was not examined in the Survey laboratory but there is little doubt that a first-class cream colored brick can be manufactured therefrom. It is unsuitable for the manufacture of either vitrified or refractory wares.

FREDONIA.

Fredonia is situated in the northwestern part of Ozaukee County and near the western margin of the lacustrine clay region.

The only brick yard in this vicinity is located about three and one-half miles northwest of Fredonia station and is owned and operated by **Carl Peterson.** The clay bank consists at the surface of one foot of black, loamy clay which is stripped. Underneath this occurs seven feet of thinly bedded blue clay streaked with yellow and brown iron oxide. Near the surface the clay is tough but deeper down it contains more sand and is easily worked. There is a considerable quantity of clay at this place but the distance from the railroad prevents any extensive develop ment.

The clay is hauled by team from the bank to the yard where it is mixed in a wooden pug mill run by horse power. The brick are moulded in a hand press having a daily output of about 5,000 brick. They are dried in hacks on the yard and burned in scove kilns. It requires fourteen days to burn the brick and about one-half cord of wood is consumed for each thousand brick burned.

The use of a moulding sand which contains a small percentage of iron oxide and some calcite imparts a grayish color to the brick when burned. The average annual output of this yard during the last three years has been about 250,000 brick. The clay is very calcareous and is suitable for the manufacture of brick and other wares that do not require vitrification or are not intended to be refractory.

GREEN BAY AND DEPERE.

The clays in the vicinity of Green Bay and De Pere are a part of the great body of lacustrine clays that occur throughout the region adjacent to the Fox River and Lakes Michigan and Winnebago. The clays differ locally in the percentages of alumina, calcium carbonate, magnesium carbonate, silicia, and iron which they contain, but in general they are high in quartz and the carbonates of calcium and magnesium, and low in alumina. Between Green Bay and De Pere the clay outcrops almost continuously along the Fox River and it is so nearly alike in all places that a general description of the clays as they occur at one place is applicable to almost the entire area from De Pere to Green Bay and even beyond. The brick which are manufactured at all the yards in this area, with two or three exceptions, are cream colored.

The brick yard owned and operated by **Hans Hansen** is located apart from the other yards, being about two and one-half miles northeast of Green Bay. The yard is situated back from the river and near the top of the table land adjacent to the river valley. Only the red burning clay which is covered with a foot of gravel and which has a thickness of two and a half feet is used.

This yard was opened in 1883 and has been operated each year since that time between May 1st and October 1st. The yard is equipped with an Anderson Chief soft mud machine but the demand for brick has not been sufficient to warrant the expense of operating it. The clay is now mixed with about one-seventh sand, soaked over night in a vat, and tempered in a wooden pug mill operated by horse power. The brick are moulded by hand, dried in hacks on the yard and on pallets under sheds, and burned in scove kilns. The brick are burned nine days and about one-half cord of soft wood is consumed for each thousand brick burned. In 1899 this yard turned out 300,000 brick, which sold at an average of $5.75 per thousand at the yard. Besides common brick Mr. Hansen manufactures special shapes for wells and arches.

Between Green Bay and De Pere, along the Fox River, six companies are manufacturing brick. As stated above, the clay which is being used by all of these companies, is essentially the same. At the surface there usually occurs from six inches to two feet of gravelly clay which requires stripping. Underneath the stripping occurs from two to four feet of clay, which, when used alone, burns red; four to twelve feet of what is known as red clay which burns a pink or cream color; and a variable thickness of clay which burns either a white or cream color. Everywhere the clay occurs in layers which are separated by thin laminae of sand. Some of these layers have a reddish brown color and others have a pink or gray tint. The colors alternate in such a manner as to give the " chocolate cake " appearance described in connection with other deposits of this region.

The layers are from a fraction of an inch to eight inches in thickness. The red layers have the greatest thickness near the top of the bank, while the light pink colored layers interlaminated with them increase in thickness toward the bottom of the bank. The light colored laminae attain a maximum thickness of from six to eight inches. The reddish brown layers are usually tough and difficult to soak while the lighter colored portions on account of their sandy nature are easily mixed with water.

The clay is everywhere jointed, on account of which it can be easily mined and reduced to a condition suitable for moulding into brick.

Streaks of limestone gravel occur in some parts of the bank and occasional pebbles occur throughout the body of the clay. Evidence of these pebbles is seen in the brick and tile which are made at the different yards. In order to remove the pebbles from the clay disintegrators and crushers are used at most of the plants.

Laboratory Examination.—The only clay from this area which was examined in the laboratory of the survey was obtained at the yard of *The William Finnegan Brick Company.* Two samples were examined,

The upper or red burning clay has a uniform dark reddish brown color. It has a smooth feeling when rubbed between the fingers although the greasiness is not that which is characteristic of kaolin. When dry the clay is very hard and brittle. It slacks readily in water, breaking down into a rather coarsely pulverulent mass which is tough and plastic. When wet the color is very much intensified being almost an Indian red.

The microscopic examination shows the clay to consist of grains ranging from .05 of a mm. to .003 mm. or less

JOHN HOCKEE'S BRICK YARD, DE PERE.

GENERAL VIEW SHOWING CLAYBANK IN FOREGROUND.

in diameter. A majority of the individuals are from .014 to .003 of a mm. in diameter. The grains not only differ considerably in size but they are also very irregular in outline.

As nearly as could be ascertained the clay consists largely of quartz, kaolin, and calcite. Calcite is not nearly as abundant a constituent as it is in many of the lacustrine clays examined, although it is present in sufficient quantity to be detected with the microscope.

The white burning clay consists of alternating pink and dark reddish brown layers between which are thin laminae of sand. The clay is jointed in such a manner that large blocks can be easily broken off from the bank. In contrast with the dark brown layers the light colored layers are moderately soft when dry.

When rubbed between the fingers the dry clay feels smooth and fine grained. It slacks readily, breaking down into large scales. When wet it is very plastic and the color is intensified.

The microscope shows that the grains are mainly less than .003 of a mm. in diameter, although a few were observed which had diameters of .014 mm. Many of the individuals are slightly stained with iron oxide and have a tendency to cluster together between the cover and object glasses. The grains are irregular in outline and unequidimensional in size.

It was scarcely possible to determine the mineralogical composition of the individuals, although some of the larger ones were recognized to be quartz. The identity of the finer particles, however, could not be determined on account of their exceedingly small size.

The chemical composition of these clays is represented by the following analyses of the clays from Finnegan's Brick Yard.

No. I is the red burning clay and No. II is the white burning clay.

	No I.	No. II.
H_2O	8.15	18.13
SiO_2	59.98	43.42
Al_2O_3	16.33	10.78
Fe_2O_3	7.10	3.60
CaO	1.02	13.68
MgO	1.97	5.92
Na_2O	1.04	0.88
K_2O	4.22	3.20
TiO_2	0.58	0.40
Total	100.39	100.01

Description of Individual Plants.

John Hockees' Brick Yard.—John Hockees owns two yards on the Fox River between De Pere and Green Bay. One is known as the "East" yard and the other as the "West" yard. At the east yard the clay is taken from the bank and soaked in a vat over night before being moulded. The brick are manufactured either in a Quaker, sand mould, soft mud machine, having a capacity of from 22,000 to 23,000 a day, or in a Penfield stiff mud machine, which has a capacity of 25,000 per day.

The brick are dried under sheds and in hacks on the yard, mainly the latter. The total capacity of the dry sheds and yard is 300,000. The brick are burned in scove kilns which have a total capacity of about 1,500,000. It requires ten days to burn the brick and three-fourths of a cord of dead pine wood is consumed for each thousand brick burned.

This plant was opened in 1869 and has been worked from May to October of each year since that time. About twenty-eight men are employed on the yard. Labor costs about $1.50 per day and the kiln run brick sold in 1899 at an average of $5.00 per M. During the last three years the average annual output of the yard has been about 2,500,000.

JOHN HOCKEE'S BRICK YARD, DE PERE.

METHOD OF DRYING.

During the fall of 1899, 50,000 brick were lost by frost owing to the exposed condition of the brick while drying.

At the west yard, Mr. Hockees manufactures both drain tile and brick. This yard was opened before the one on the east side but is worked in essentially the same manner. Red, cream, and mixed colored brick, both soft and stiff mud, are manufactured. The brick are dried in hacks on the yard and burned in uncovered scove kilns. Kilns are erected as needed and the capacity is therefore practically unlimited. The brick are burned with wood and about the same amount of fuel is required as at the east yard.

The brick yard owned and operated by **John Roffers** was opened in 1887, and has been worked each year since that time from May 15th to September 15th. Red, white, and mixed colored brick and drain tile are manufactured. The clay is worked directly from the bank for the manufacture of both brick and tile. The yard is equipped with a Kels and Son brick and tile machine, a Brewer stiff mud machine, and an Eagle soft mud machine. The clay is transported from the bank to the sheds on cars operated by cable and winding drum. The brick and tile are dried under sheds constructed for this purpose and are burned mainly in scove kilns. It requires from nine to eleven days to burn the brick and three-fourths of a cord of dead pine wood is consumed for each thousand brick burned. The tile are mainly burned in round up draft kilns.

During the last three years the output of the yard has averaged from 10,000 to 100,000 tile of different sizes, and from 1,500,000 to 2,250,000 brick. The tile sold in 1899 at from $8.00 to $25.00 while brick brought $5.75 per M. kiln run. During the fall of 1899, 50,000 brick were lost through frost.

The yard owned and operated by **John Van Laanan** was opened in 1869, and is known as the "old Baeden yard." It is worked from May 10th to September 20th of each year. The yard gives employment to sixteen men besides the owner.

The clay is hauled to vats and soaked over night before being moulded into brick. Difficulty is experienced in preparing the white burning clay unless it is plowed and allowed to weather. The brick are moulded in a soft mud, sand mould machine, operated by horse power, dried under sheds and in hacks on the yard, and burned in scove kilns The capacity of the dry yard is about 240,000. The kiln capacity is about 290,000. It requires from ten to eleven days to burn the brick and one-half cord of dead pine wood is consumed for each thousand brick burned.

This yard suffered a loss of 20,000 brick in 1899 from the same frost that destroyed the brick in the previously described yards.

The yard owned by **John Baden** was opened in 1886, and has been operated each year since that time. About three and one-half or four feet of the red burning clay and one and one-half to two feet of the white burning clay were formerly used at this yard but at present all the brick are made from the red burning clay. The clay is soaked in vats and then tempered in pug mills operated by horse power. The brick are made in a "Reliable" hand press, soft mud machine which is moved on a track connecting the vats in which the clay is soaked. The yard is equipped with a Frey-Scheckler Auger machine which is not used at present.

The brick are dried in hacks on the yard and under sheds. The total capacity of the dry sheds and yard is about 200,000. The brick are burned in scove kilns which have a total capacity of about 1,000,000 brick. It requires from ten to twelve days to burn the brick and from one-half to one-third of a cord of soft wood is consumed for each thousand brick burned.

The Riverside Brick Company, owned and operated by *Smith Brothers* of Green Bay, is situated about one and one-half miles north of De Pere. The yard was opened in 1895 and has been operated each year since that time from May 10th to October 1st. The clay at this yard has a depth of about twelve feet, one-third of which is red burning. The clay

THE WILLIAM FINNEGAN BRICK YARD, GREEN BAY.

is moved directly from the bank to the machine without weathering or soaking. For the manufacture of stiff mud brick one-third red burning clay and two-thirds white burning clay are used. For the manufacture of soft mud brick only two-fifths of the white bnrning clay is used.

The clay is transferred from the bank to the machine on cars operated by a cable and winding drum. It is passed through a crusher and from thence into a pug mill where it is tempered for the manufacture of both the soft and stiff mud brick. The soft mud machine is a Jonathan Creager and Sons and the stiff mud machine is a "Big Wonder." From the pug mill the clay either drops directly into the stiff mud machine or is transferred on a belt conveyor to the soft mud machine.

The brick are dried in a Wolff drier which holds 85 cars, each of which carries 775 brick. It requires from 24 to 26 hours to dry the brick, after which they are taken to the kiln sheds and stacked ready for burning. The brick are burned in scove kilns. It requires from ten to fourteen days to burn the brick, pine slabs being used for fuel. In 1899 the company manufactured about two million brick.

The **William Finnegan Brick Yard** is located on the west side of the Fox river near the outskirts of the city of Green Bay. Only dry pressed brick are manufactured. The machine now used is one of the earlier Boyd patents and has a capacity of about 16,000 a day.

The clay is plowed in the bank and allowed to dry, after which it is hauled into the sheds and passed through a Stedman pulverizer. The red and white clays are either used separately or mixed, depending upon the color desired. By mixing the clays in the proper proportions either white, cream, red, or mottled brick can be obtained. The brick are transferred directly from the machine to scove kilns in which they are burned. The brick are burned very slowly, about three weeks being required to finish a kiln.

The yard is well provided with transportation facilities, tracks having been extended to this yard from both the Chicago and Northwestern and Chicago, Milwaukee and St. Paul railroads.

The brick which are manufactured have an excellent appearance and are among the best dry press brick manufactured within the state. The yard was opened in 1893 and has been operated about four months of each year since that time. The average annual output during the last three years has been about three million brick. The market for the brick is largely in the upper peninsular of Michigan. The laboratory examination of the clay from this yard is given on pp. 92 to 94.

HIKA.

The village of Hika is located on Lake Michigan in the extreme southeastern corner of Manitowoc County. The lacustrine clay is exposed along the shore of the lake for some distance at this place and has a thickness of from five to ten feet. The clay which is being exploited at the brick yards is overlain with four feet of sand and gravel and rests upon an unknown thickness of sand.

Two brick yards are located at this place, one of which is owned and operated by August Witte and Son and the other by Albert Kohn.

The brick yard owned by **August Witte and Son** was opened in 1876 and has been operated nearly every year since that time. The clay is mixed with one-third sand, after which it is tempered in wooden pug mills operated by horse power. The brick are moulded by hand, dried in hacks on the yard, and burned in scove kilns. It requires about one hundred cords of wood to burn a kiln of 180,000 brick. The brick have a white or cream color.

During the last three years the average annual output of this yard has been about 250,000 brick. They sold in 1899 for $6.00 to $7.00 per M. kiln run at the yard.

THE WILLIAM FINNEGAN BRICK YARD, GREEN BAY.

ONE OF THE KILNS.

The brick yard of **Albert Kohn** is directly south of that owned by August Witte and Son. The top of the clay bank at this place consists of red clay which passes below into a sandy, laminated clay having a bluish color. The clay is taken from the bank and weathered before soaking. After soaking in a vat it is pugged and moulded in the same manner as described for the previous yard. The brick are dried in hacks on the yard and burned in scove kilns.

KAUKAUNA.

The Kaukauna Brick Yard is located on the west bank of the Fox River, on section 18, town 21, range 9 E., and is owned and operated by Lindauer and Rhode. It was opened in 1889 and has been operated each year since that time between May 1st and September 15th. The company manufactures common brick which were sold at the yard in 1899 for $4.75 per M. kiln run. During the last two years the average annual output has been in the neighborhood of 1,200,000.

The clay bank consists at the surface of from four to ten feet of massive clay through which is scattered small boulders and occasional pebbles. Underneath this occurs thirty feet of clay in layers from one to three inches in thickness, each of which is separated by a thin laminae of quick sand from one-eighth to one-half inch in thickness. The clay layers near the top have a reddish brown color, but deeper within the bank the color changes to a grayish yellow. Below the clay occurs a bed of yellow sand interlaminated with which are occasional thin layers of clay. Near the bottom of the clay bank occurs a thin layer of gravel. Occasional pebbles are scattered throughout the bank. The clay is broken into irregular and polygonal blocks by numerous plane and spherical joints. The clay for a depth of from four to ten feet contains so much limestone gravel that is unfit for use and is consequently stripped. The thirty feet underneath this stripping

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is all used in the manufacture of brick. The clay is mixed with sand, passed through a Potts disintegrator, and tempered in an Anderson pug mill connected with an Anderson soft mud machine.

The clay from the lower six to ten feet of the bank burns almost white, while that above burns red or pink. The white color of the brick as they are now burned is partly due to the calcium carbonate in the sand which is mixed with the clay.

The brick are dried in hacks on the yard and burned in scove kilns. The capacity of the dry yard is about 150,000 and the kiln capacity is about 600,000. The brick are burned from seven to eight days and about one-third of a cord of wood is consumed in burning each thousand brick.

Laboratory Examination.—The clay examined in the laboratory was composed of dark reddish brown layers separated from each other by thin laminae of arenaceous clay having a pinkish color. The reddish brown layers are brittle and hard when dry and the others are soft and friable.

The clay having the reddish brown color slacks modererately fast breaking down into large thin scales or flakes. The pinkish colored layers break down more quickly forming a pulverulent mass resembling fine sand. The clay is very plastic and the color is much intensified by wetting.

The microscopic examination shows that the pink colored layers consist of grains of very uniform size ranging from .009 to .003 mm. in diameter. The grains are very irregular and angular in outline. Their mineralogical identity was not determined.

The reddish brown layers consist of grains which are less than .003 of a mm. in diameter. They are stained yellowish brown with iron oxide and are very much smaller than the grains in the pinkish colored layers.

The sand which is mixed with the clay and also that which is used for moulding has a yellowish color and is flecked with small dark grains of iron oxide. The largest grains observed had a diameter of about .33 mm. The average grains are from .10 to .05 mm. in diameter. Many of the grains are rudely angular in shape, others are sharp and angular, and a few are well rounded. The microscopic examination shows that about one-third of the sand is calcite or dolomite, slightly stained with iron oxide. The high percentage of calcite, however, obscures not only the color which might be imparted by the iron in the sand but also that which would ordinarily result from burning the clay.

The use of calcareous sand similar to this is frequently very troublesome on account of its fusibility which often causes the brick to stick together in the kiln.

KENOSHA.

Kenosha is situated on Lake Michigan in the east central part of Kenosha County. The clays occurring at this place are a part of the lacustrine deposits and do not differ essentially from those already described.

The plant owned and operated by **W. J. Craney** is about a mile southwest of the city. The clay bank consists of six feet of red clay at the surface, underneath which occurs one-half foot of sand, one foot of tough clay carrying limestone gravel, and an unknown thickness of blue clay, six feet of which is now being used. After the clay is taken from the bank it is mixed with one-tenth sand, passed through a crusher, and tempered in two pug mills. The clay then goes to a Monarch soft mud machine in which the brick are moulded. The machine, as operated, has a capacity of about 23,000 brick per day. The brick are dried in hacks on the yard and burned in scove kilns. The kiln capacity is about 200,000.

The yard was opened in 1887 and has been worked each year since that time, between May and October. During the last three years the average annual output has been in the neighborhood of a million brick. The average selling price in 1899 was about $6.00 per M. kiln run.

The Engel Brick Yard which is operated by *C. Brockenhauser*, is in the south part of the city near the Chicago & Northwestern railroad. This yard was opened in 1872, and has been operated each year since that time from May to October. The clay bank consists of nine feet of stripping and nine feet of workable clay. The clay is laminated and works much better after having been weathered through a winter than when used directly from the bank. The clay is mixed with sand in the proportion of two of clay to one of sand. A shovelfull of fine coal is mixed with each half yard of clay to assist in the burning. The clay is passed through a disintegrator and pug mill and the brick are moulded in an Anderson soft mud machine, the capacity of which is 28,000 brick per day. The brick are dried on pallets under sheds and in hacks on the yard and burned in scove kilns. Soft wood and coal are used for fuel and it requires about six or seven cords of wood and two tons of coal for each 25,000 brick burned.

The average annual output of this yard during the last three years has been about 1,500,000. The brick sold mainly in the vicinity of Kenosha and in 1899 sold for $6.00 to $8.00 per M.

During a week of rain the company lost 40,000 brick which were drying in hacks on the yard. Losses from this source are not unusual where brick are dried without adequate protection from sudden storms.

KEWAUNEE.

The clay which is used for the manufacture of brick at Kewaunee is obtained from the lacusturine clay formation. Underneath from two to ten feet of sand and gravel occurs seven to nine feet of red clay which is interstratified with sand. Underneath the red clay is an unknown thickness of blue clay which is now worked to a depth of about six feet. Both the red and blue clays contain an occasional lime stone pebble.

The Kewaunee Brick Yard, which is operated by *John Bergman,* is situated about one mile west of the lake shore. The clay is taken from three different banks and the brick are molded in a "Reliable" hand press machine. The brick are dried on pallets under sheds and in hacks on the yard and burned in scove kilns. It requires from ten to twelve days to burn the brick, and about three-fourths of a cord of mixed wood is consumed for each thousand brick burned.

A short distance west of the Kewaunee Brick Yard is a yard owned by **J. Strew.** At this plant the clay is soaked in vats after being taken from the bank. The brick are moulded in a "Reliable" machine, dried on pallets under sheds and in hacks on the yard, and burned in scove kilns.

The brick from both yards are white or cream colored. An occasional limestone pebble occurs in the clay on account of which some of the brick are badly blistered.

KIEL.

Kiel is located in the southwest corner of Manitowoc County. The brick yard at this place which is owned and operated by **August Kamptz** is situated near the south bank of the Sheboygan River and about one and one-half miles northeast of the village.

The surface of the clay bank consists of two feet of peat and muck which is stripped. Underneath this occurs three feet of blue clay in which there are many small shells forming almost a marl; one to one and one-half feet of gravel; and an unknown depth of bluish gray clay. The brick are made in a Kels and Sons stiff mud machine and are dried in hacks under low sheds. The brick are burned in a permanent up draft kiln constructed mainly out of granite boulders but lined on the inside with brick. The fire places are outside of the kiln proper and are so constructed that the flame never comes in contact with the brick.

The brick in the kiln that were examined were not burned uniformly hard and showed an occasional limestone pebble.

MANITOWOC.

The clay which occurs in the vicinity of Manitowoc is a part of the lacustrine deposit. During the last thirty or forty years the clay in this locality has been exploited very extensively for the manufacture of brick. Ten brick plants are now located in and about this city. The clay which occurs at the various yards does not differ materially from that which is found in other parts of the lake region. The following are typical sections of the clay banks as they occur at several of the yards.

The yard owned and operated by George Fricke, deceased, shows the following succession from the surface down:

6 to 8 feet boulder clay and sand,
4 feet red clay,
12 feet of blue clay, which becomes somewhat sandy toward the bottom,
8 feet blue clay, not used,
Hard pan consisting of clay and gravel.

The clay bank which is worked by P. J. Kauffmann has a total depth of 73 feet, underneath which gravel occurs. The following is a description of the bank from the surface down:

2 to 5 feet of red clay and gravel, which is stripped,
6 to 8 feet of red clay,
14 to 15 feet of blue clay, distinctly laminated,
45 feet of blue clay, not used.

The line of separation between the red and blue clays is very irregular in this bank. They apparently grade into each other.

The clay bank worked by Andrew Schradwsky shows the following succession:

6 to 7 feet of sand and gravel, which is stripped,
3 to 4 feet of interlaminated clay and sand containing an occasional pebble or boulder,
14 to 16 feet of blue clay, interlaminated with streaks of red clay. A few pebbles were observed.

The clay bank worked by the Manitowoc Clay Company shows the following succession:

3 to 4 feet of red burning clay,

8 to 10 feet of red clay which burns white, containing limestone gravel and boulders,

12 to 14 feet of blue clay exhibiting weak stratification planes and containing occasional pebbles of limestone.

The clay bank owned by Edward Fricke shows the following succession:

1 to 1½ feet of red clay which is stripped,

16 to 18 feet of thinly laminated red and blue clay.

About six feet from the bottom of this clay bank there is a thickness of 2½ feet of crumpled layers of clay and sand. The plications continue for a distance of about 75 feet and then apparently die out. This clay bank is on the lake shore and it is claimed that during the last thirty years the lake has encroached upon the land at this place at least fifty feet.*

Well borings made at the yard owned and operated by Stephen Bertler and Son shows a depth of sixty feet of clay, part of which contains gravel.

Most of the plants in this vicinity are poorly equipped for making brick. In many cases the machinery is old and inefficient while the methods of drying and burning are of the most primitive kind.

At the yard owned by **George Fricke** the brick are moulded by hand, dried in hacks on the yard, and burned in scove kilns. The clay is mixed with one-half sand and tempered in wooden pug mills operated by horse power. The brick stick together in the kiln owing to the use of a calcareous moulding sand.

At **P. J. Kaufmann's** plant the brick are also moulded by hand, dried in hacks on the yard, and burned in scove kilns. It requires about nine days to burn the brick and one-half cord of wood is consumed for each thousand brick burned. One-third sand is mixed with the clay.

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*For cases where accurate measurements have been made the reader is referred to the Geology of Wisconsin, Vol II, pp. 230-233.—T. C. Chamberlin.

At **Andrew Schradwsky's** yard the clay is tempered in wooden pug mills operated by horse power. The brick are moulded by hand, dried in hacks on the yard, and burned in scove kilns.

At **Joseph Krejwski's** yard, which is located three blocks north-west of the city limits, the clay is mixed with one-third sand and soaked over night in a vat. The brick are moulded by hand, dried in hacks on the yard, and burned in scove kilns. One of the kilns has been cut out of the clay bank, and the natural clay forms the walls of the kiln.

Franz Waerful's yard joins the yard just described. Here the clay is mixed with sand in the proportions of eight of clay to five of sand and tempered in wooden pug mills run by horse power. The brick are moulded by hand, dried in hacks on the yard, and burned in scove kilns. In this yard there has been an attempt to economize labor by using a track and cars to convey the clay from the bank to the pug mill and for hauling the brick from the hacks to the kiln.

The yard owned by **Edward Fricke** is located just south of where the Little Manitowoc River empties into the lake. The clay is tempered in horse power pug mills. The brick are moulded by hand, dried in hacks on the yard, and burned in scove kilns.

Stephen Bertler and Son have operated for a number of years a yard immediately adjacent to that owned by Edward Fricke. This yard, however, was abandoned in 1899, and a new one has been opened about a half a mile distant. The clay is tempered in wooden pug mills run by horse power. The brick are moulded by hand, dried in hacks on the yard, and burned in scove kilns. The old yard was equipped with Cream City and Penfield brick machines, neither of which are used at the new yard.

At the **William Fricke** yard the clay is mixed with about one-eighth sand and tempered in horse power pug mills. The brick are moulded by hand, dried in hacks on the yard, and burned in scove kilns.

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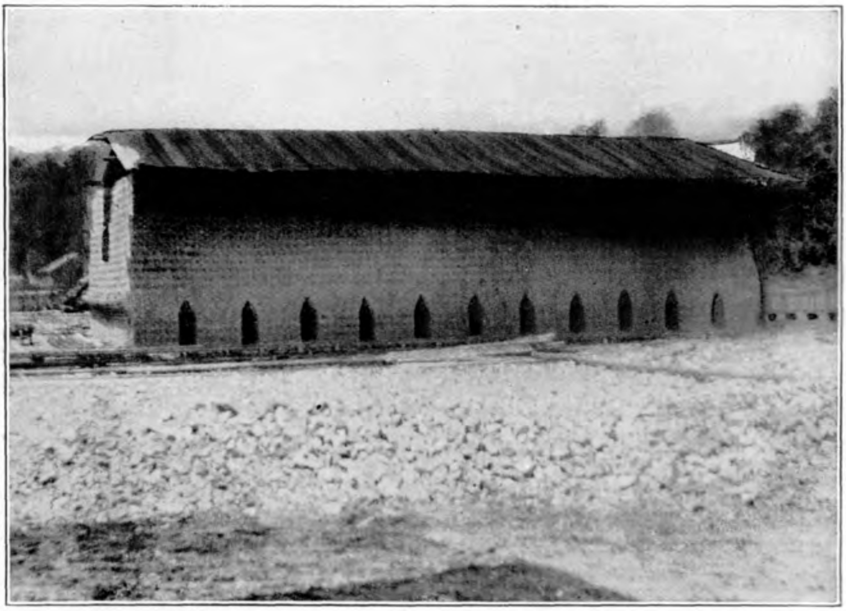


2

TYPICAL SCOVE KILNS.

The last company to begin operations at this place was **The Manitowoc Clay Company** of which *F. E. Dickinson* is owner. The clay is transported from the bank on dump cars and run through a Wellington disintegrator. It is mixed with one quarter sand and tempered in a pug mill attached to the Wellington soft mud machine in which the brick are moulded. The brick are dried in a Standard steam drier, which has a capacity of about 94,000 brick, and also on pallets under sheds. The brick are burned in scove kilns which have a total capacity of about 1,200,000. During 1900 the company intend to install a Penfield auger machine and a Boyd dry press. It is the purpose of the company to also manufacture hollow building blocks. The plant will then be equipped to turn out in the neighborhood of 100,000 brick a day. During 1899, there was an average of 42 men employed on the yard. The output that year was about 2,200,000 brick.

The average annual output of the other brick yards in the vicinity of Manitowoc is from 100,000 to 700,000. The total output of the Manitowoc yards for 1899 was between five and six million brick.

MARENGO.

Edward Hartmann who operated the yard at Ashland for a number of years has installed a plant near Marengo and is manufacturing common brick. The clay at this place has a deep reddish brown color and is very similar to that which occurs throughout the region adjacent to Lake Superior. A chemical analysis of this clay is given in table I.

MILWAUKEE AND WAUWAUTOSA.

The five brick yards which are now operated in the vicinity of Milwaukee and Wauwautosa are supplied with clay which does not differ materially from that which occurs in other parts of the lake area. There are naturally local differences in the thickness of the beds, abundance of gravel, etc., but in general, the exposures consist of an upper clay which has a reddish color and a lower which is grayish blue. At some of the yards the clay is worked to a depth of forty feet, the water being either drained off or pumped out. Gravel and boulders of various kinds and sizes are found in some parts of all the clay banks examined. Most of the clay is laminated but the lower blue clay often appears to be void of stratification planes. At several of the yards it is necessary to strip from three to four feet of the surface clay on account of the boulders and gravel which it contains. Lenses of clay carrying numerous pebbles of limestone occasionally occur in the body of the workable clay itself. To destroy the pebbles or separate them from the clay, each of the yards is equipped with crushers and disintegrators through which all the clay passes.

Typical exposures of the clay for this area can be observed either at the Howell Avenue yard, owned and operated by Burnham Brothers, at the Chase Brick yard, now operated by Burnham Brothers, or at the yard owned by the Kraatz estate, located in Wauwautosa.*

At several of the yards the clay bank is worked by plowing and scraping and at others it is worked with pick and shovel. At the Lincoln Avenue yard a steam shovel is used. Dump cars hauled by horses, and cable cars operated by a steam hoist are the means employed for transporting the clay from the bank to the works.

At some of the yards sand is mixed with the clay; at others, fine coal screenings are used; and at two of the yards burned bats are ground and mixed with the clay.

The brick are manufactured by the stiff mud, soft mud, and dry press methods, all three being employed at some of the yards. In preparing the clay for the dry press it is usually dried under sheds, ground in a dry pan, and care-

* Plates showing the relation of the clay, drift, and sand beds are given in Vol. III, of the Geology of Wisconsin by T. C. Chamberlin. For various reasons it was deemed best not to reproduce these sections in this report.

fully screened. The clays are usually used in the proportion of one of blue to four of red. The clay which is being used for the manufacture of stiff and soft mud brick is always passed through a crusher or disintegrator, and is usually well tempered in a pug mill before being moulded into brick.

The brick are dried either on pallets under sheds or in patent driers.

The brick are burned mainly in scove kilns. The customary method of firing the scove kilns is to burn one side at a time. When one side has been completely burned the door is sealed up and the other side fired. The Milwaukee Brick Company is equipped with a continuous kiln, while several permanent up draft kilns have been built at the different yards. No round or square down draft kilns are used for burning the brick.

The brick which are manufactured in Milwaukee and vicinity are known throughout the country as cream colored brick, although the color varies from white to yellowish green, depending upon the temperature at which the brick have been burned. Some of the brick which are underburned have a faint pinkish color.

Burnham Brothers own what is known as the Howell avenue yard, and also the west yard located near Wauwautosa.

The Howell Avenue yard is equipped with stiff mud, soft mud, and dry press machinery. The clay used in the manufacture of soft mud brick is mixed with a small percentage of fine coal before being tempered. The red and blue clays which are used for the manufacture of dry press brick are spread in alternate layers under sheds where they are dried. When used they are thoroughly mixed in the proportion of one to four. For the manufacture of dry press brick, the clay is used in a very damp condition. The brick are all burned in scove kilns. The dry press brick are frequently placed in the center of the kiln and the stiff and soft mud brick on the outside.

The Lincoln Avenue yard, which is owned by the *Chase Brick Company* is equipped with crushers, screens, soft mud, stiff mud, and dry press machinery. The process of manufacture in each case is very similar to that of the Howell Avenue yard described above. The soft mud brick are dried in a patent drier while the stiff mud brick are dried on pallets under sheds.

The yard owned by the **The Milwaukee Brick Company** is located a short distance north of Wauwautosa and is one of the last yards to be established in this area. The clay bank is shallow, having been worked to a depth of only about ten feet. The bank is plowed and the clay transferred by means of a wheeled scraper to a shed where it is prepared for the dry press machine. The clay which is used for manufacturing stiff mud brick is moved from the bank to mill on cars operated by cable and winding drum. All of the clay is passed through a crusher or disintegrator to either pulverize or separate the gravel from the clay. The clay which is used for making dry press brick is mixed with pulverized brick bats and passed through a screen having meshes of one-sixth to one-eight of an inch and inclined to an angle of about forty-five degrees.

The yard is equipped with stiff mud and dry press machinery. The company has installed a coke and steam drier with a capacity of about 71,000 brick. This yard is also equipped with a continuous kiln having fourteen chambers, each of which has a capacity of 28,000 brick. This kiln is reported to be less expensive than other kilns and operates satisfactorily. The yard is also equipped with several scove kilns in which the stiff mud brick are burned.

At the west, or **Wauwatosa yard**, which is owned and operated by *Burnham Brothers*, only stiff mud brick are manufactured. The clay is taken from the bank and dumped from the cars into a vat where it is partially mixed with water. From the vat it is run into a pug mill and from thence through a crusher and disintegrator. The clay passes from the disintegrator into a second pug mill where it is finally mixed with water and tempered. The clay passes from this pug mill into a Chambers stiff mud machine which is equipped with an automatic end cut off. The brick are dried in a Standard drier and burned in scove kilns. Wood and coal are used for fuel.

The brick plant owned by **The Kranz estate** is adjacent to the yard just described. The clay bank at this place is from ten to fifty feet deep and exposes some very excellent clay. The yard is equipped with dry press and soft mud machinery. The clay is moved from the bank to the mill on dump cars operated by horse power. All the clay is passed through a crusher before being used. For the manufacture of soft mud brick the clay is thoroughly tempered in a pug mill before being moulded. The brick are dried on pallets under sheds and burned in scove kilns. Brick bats are ground in a dry pan and mixed with the clay used for making dry press brick.

It has been found that by mixing this grog with the clay it is unnecessary to thoroughly dry the brick before setting in the kiln. In the manufacture of the dry press brick the clay used is very damp.

All the brick are burned in scove kilns. The dry press brick are usually placed in the center of the kiln where they receive the highest heat.

The yard formerly owned by **The Cream City Brick Company** has not been operated for several years. The property is located in a portion of the city where land is relatively high and the sheds are in such a dilapidated condition that the yard will probably never be operated again.

The yard owned by **Devaaler and Sons** is also idle at the present time. The yard is equipped with suitable machinery for the manufacture of common brick and there is an abundance of clay easily available. The yard is leased at the present time by the Milwaukee Building Supply Company and will probably not be operated until the demand for brick increases beyond the capacity of the other yards.

The **Standard Brick Company** of which *E. W. Drake* is president owns a yard situated near the yard of Devaaler and Sons. This plant has not been operated for several years, owing to the insufficient demand for building brick.

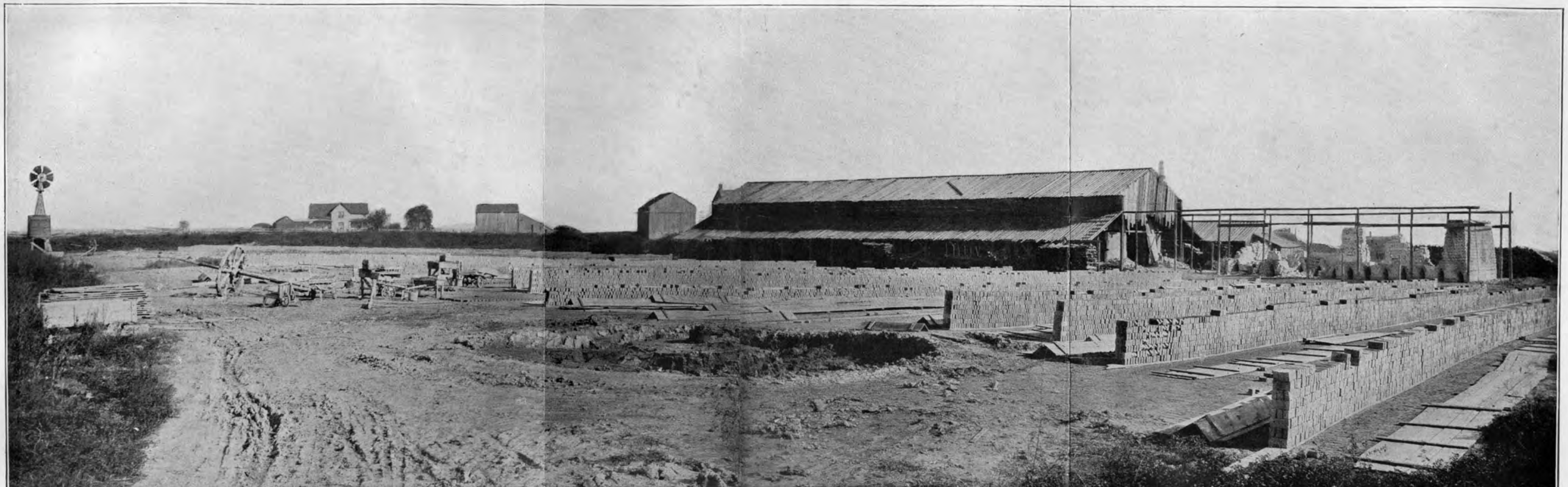
During the last three years Burnham Brothers have manufactured in the neighborhood of three and a half to four and a half millions of brick per year. Devaaler and Sons manufactured all the way from 600,000 to 3,500,000 brick per year. The Chase Brick Company manufactured all the way from ten to seventeen millions of brick a year. The brick have nearly all been sold in the vicinity of Milwaukee. During the year 1899, prices ranged from $4.50 to $10.00 per M.

The clays in the vicinity of Milwaukee are very calcareous as shown by the chemical analyses. They are not suitable for the manufacture of either refractory or vitrified ware, although they make one of the best common building bricks in the country. The clay is suitable for the manufacture of most clay wares with a white body, which do not require vitrification and will not be used in places of high temperature.

NEENAH.

The clay which occurs in the vicinity of Neenah has the same general characteristics as that occurring in other parts of the lacustrine clay area. One brick yard known as the **Neenah Brick Yard** is located at this place. It is owned and operated by *Louis Hanke.* The clay has a workable depth of about ten feet, is thinly laminated, and has a general reddish color. Below the level to which the clay is now being worked the bank is filled with stumps and logs which apparently drifted in before the deposition of the clay above. The clay is jointed and separates readily in huge masses from the bank.

The clay is hauled from the bank, mixed with sand, and



HILKER BROTHERS NORTH POINT BRICK YARD, NEAR RACINE.

tempered in a pug mill connected with the brick machine. The brick are made in a Sword machine, dried in hacks on the yard, and burned in scove kilns. The capacity of the dry yard is 225,000 and the kiln capacity is about 2,000,000. It requires six days to burn the brick and one-third of a cord of wood is consumed for each thousand brick burned. The brick have a white or cream color.

This yard was opened in 1891 and has been operated each year since that time, with the exception of 1895, 1896, and 1897. In 1898 the output was about one million brick. In 1899 the brick sold at an average of $5.50 per M. kiln run.

NEW LONDON.

Throughout the valley of the Wolf River from Lake Winnebago to Shawano there are extensive deposits of clay of the same character as those which occur in the Fox River valley. Between New London and a point several miles north of Shiocton there are numerous exposures of clay along the river banks.

Two brick yards are now operated near New London. One is owned by August Prahl and the other by Frederick Zerrenner and Son.

Prahl's Brick Yard is east of New London, south of the Embarass River, and one-fourth of a mile north of the Green Bay and Western railroad. The clay is reported to have a depth of over one hundred feet, although it is now worked to a depth of only six feet. The clay at the surface for a depth of two feet burns red while that underneath burns white. When the two clays are mixed together they burn a cream color. The clay is pugged and moulded in a Wellington soft mud machine. The brick are dried in hacks on the yard and burned in scove kilns.

The total kiln capacity is 300,000. It requires eight days to burn the brick, and a little over one-third of a cord of wood is consumed for each thousand brick burned.

Owing to the imperfect manner in which the red and white burning clays are mixed the brick are variegated with streaks of white and red. If more care were exercised in mixing the clays there would be greater uniformity in the color of the brick. In order to give the brick a red color, a moulding sand which burns red is used. This might be unnecessary if the bank was properly worked.

The yard owned and operated by **Frederick Zerrenner and Son** is located north of New London on the Chicago and Northwestern Railroad. The clay is worked to a depth of ten or twelve feet down to the water level. The surface of the bank consists of two feet of soil which is stripped. Underneath this occurs two feet of red burning clay, eight to ten feet finely laminated white burning clay, and an unknown depth of sand. The clay contains an occasional pebble of limestone.

The clay is passed through a Potts disintegrator and the brick are manufactured in a Potts soft mud machine. The brick are dried on pallets under sheds and burned in scove kilns. The pallet sheds have a capacity of about 100,000 and the kiln capacity is 600,000. It requires from nine to ten days to burn the brick and from one-half to three-fourths of a cord of wood is used for each thousand brick burned.

The yard was opened in the spring of 1898, during which year 600,000 brick were manufactured. In 1899 the plant manufactured about a million brick, which sold for about $5.00 per M. kiln run.

NORTH CAPE.

North Cape is situated in the central part of Racine County, near the western margin of the lacustrine clay area as mapped by the former Geological Survey. The clay bank at this place has a depth of about ten or twelve feet below the stripping of sod and soil. The brick and tile plant of **The North Cape Brick and Tile Manufacturing**

Company, which is located here was idle when visited in the summer of 1899, on account of which the clay bank was not in condition to be carefully examined.

The plant is equipped with a Brewer brick and tile machine, a crusher, belt elevator, and vats for soaking the clay. The brick and tile are dried under sheds, which are equipped with steam pipes for supplying artificial heat, and burned in round, down draft kilns in which wood is used for fuel.

The brick and tile have a buff, white, and sometimes light red color, depending mainly upon the proportions of red and white burning clay which are used.

OSHKOSH.

No brick are manufactured in Oshkosh at the present time, although extensive deposits of lacustrine clay occur directly west of the city. On lake Buttes des Morts which is about eight miles west of the city, a dark reddish brown clay occurs which is comparatively free from limestone gravel. The deposit is very near the lake and if brick were manufactured at this place they could be easily transported on scows to any part of Lake Winnebago. This clay has been analyzed and otherwise examined in the laboratory of the Survey. The composition of the clay is given in table I. It will be seen by reference to the analyses that the clay is very calcareous and unsuitable for the manufacture of either refractory or vitrified wares. It is well adapted to the manufacture of brick, drain tile, and similar non-vitrified wares.

Part of the land on which the clay occurs is owned by *John W. Schultz* of Oshkosh.

The Cook and Brown Lime and Stone Company furnish a large part of the brick used in Oshkosh and vicinity. The plant from which the brick are obtained is located at Stockbridge which is on the east side of Lake Winnebago directly across from Oshkosh. The plant at this place is described on a following page.

PLYMOUTH.

Plymouth is situated in the north central part of Sheboygan County and is in the lacustrine clay area. The only brick yard in this vicinity is owned and operated by **Otto Krauss**. At the time the plant was examined in 1899 it had been idle for several months, on account of which the examination of the clay bank was unsatisfactory.

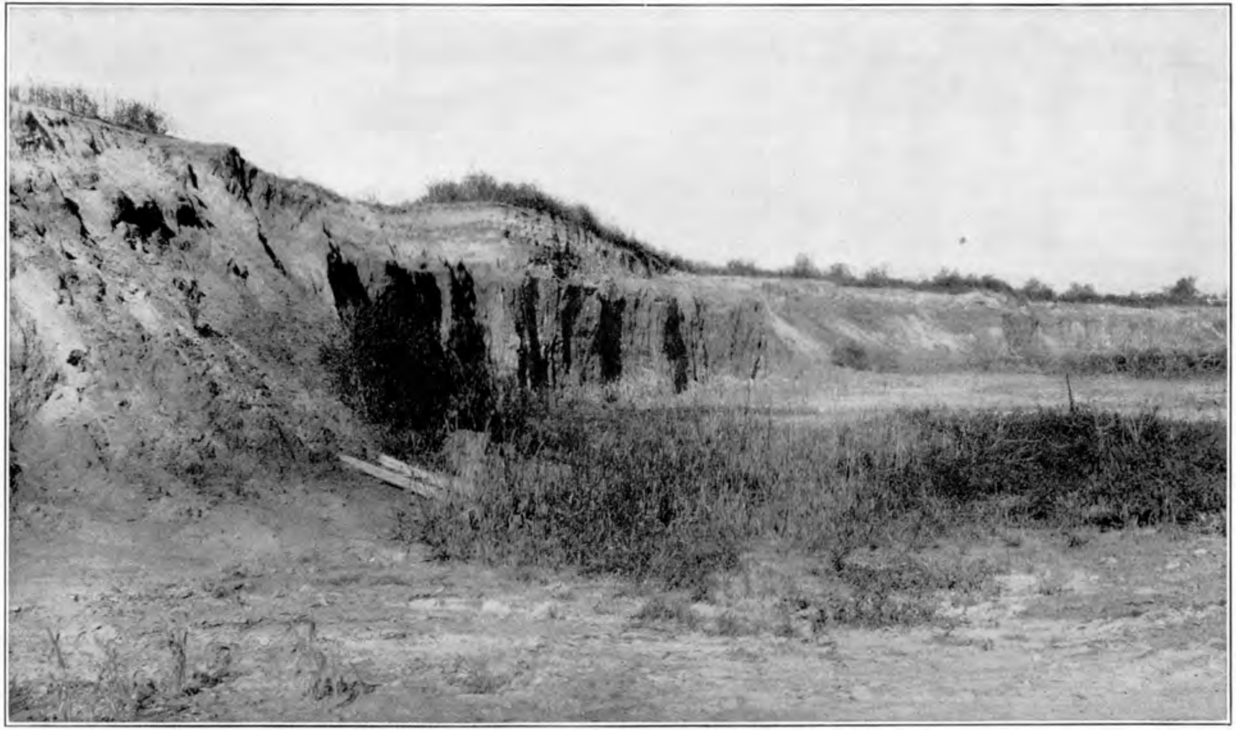
The clay is known, however, to be essentially similar to that which occurs throughout the lake region. Occasional pebbles of limestone require that the clay be passed through a crusher or disintegrator before being moulded into brick. The brick are manufactured in a stiff mud machine having a side cut-off. They are dried in hacks on the yard and burned in scove kilns. It requires about twelve days to burn the brick, and when properly burned they have a cream color.

PORT WASHINGTON.

Two brick yards are located in Port Washington, both of which are situated near the lake shore.

The yard owned and operated by **Schramke Brothers** is in the south part of the city and the clay is mined from a bank having a total thickness of about one hundred feet. The upper thirty or forty feet of the clay contains limestone gravel and other rock, on account of which it is either screened or crushed before using. Twenty-five feet of the top clay is used in the manufacture of dry press brick. The next twenty-five feet is used for the manufacture of stiff mud brick. Underneath this there occurs about fourteen feet of sand and twenty-five feet of blue clay, the latter of which is used in the manufacture of stiff mud brick.

Both stiff mud and dry press brick are manufactured.



HILKER BROTHERS NORTH POINT BRICK YARD, RACINE.

CLAY BANK, TYPICAL FOR THE LACUSTRINE AREA.

The stiff mud brick are dried in hacks on the yard and burned in scove kilns. The capacity of the dry yard is about 85,000 and the kiln capacity is 900,000. This yard was opened in 1897 and the output during the last three years has averaged nearly one million brick.

Guenther & Sons' Brick Yard is situated in the north part of the city. The clay bank consists of a stripping of from fifteen to eighteen feet of red clay which contains limestone gravel; three to four feet of sand; and twenty to twenty-two feet of blue clay which is practically free from stone. The lower twenty feet is the portion of the clay which is used for making brick.

At Guenther & Sons' plant the clay is mixed with a small quantity of sand and passed through a crusher. The brick are made in a "Little Wonder" machine to which is attached a Raymond cut off. The brick are dried in hacks on the yard and burned in scove kilns. It requires from eleven to twelve days to burn the brick and about one-half cord of wood is consumed for each thousand brick burned. Besides being used for the manufacture of brick and drain tile the clay from this bank is dried in sheds and shipped to Milwaukee where it is used to pack steam pipes. The brick and tile which are manufactured at this place are among the best that were observed in the lake region.

Laboratory Examination.— The clay from Guenther & Sons' brick yard was examined in the laboratory of the Survey and was found to be very plastic but without any distinguishing odor or taste. It slacks readily in water, breaking down into a very fine powder. The largest grains observed under the microscope were about .025 of a mm. in diameter. The smallest were less than .001 mm. in diameter. The average grains have a diameter of about .0058 mm. The grains in this clay have a tendency to cluster together, as noted in some of those previously described.

The grains are sub-angular in shape and unequidimensional in size. The clay consists mainly of quartz, calcite, and an undetermined quantity of kaolin. The chemical composition of the clay is given below.

H_2O	20.90
SiO_2	38.54
Al_2O_3	10.94
Fe_2O_3	3.60
CaO	14.02
MgO	7.88
Na_2O	1.00
K_2O	2.80
TiO_2	0.40
MnO	trace
Total	100.08

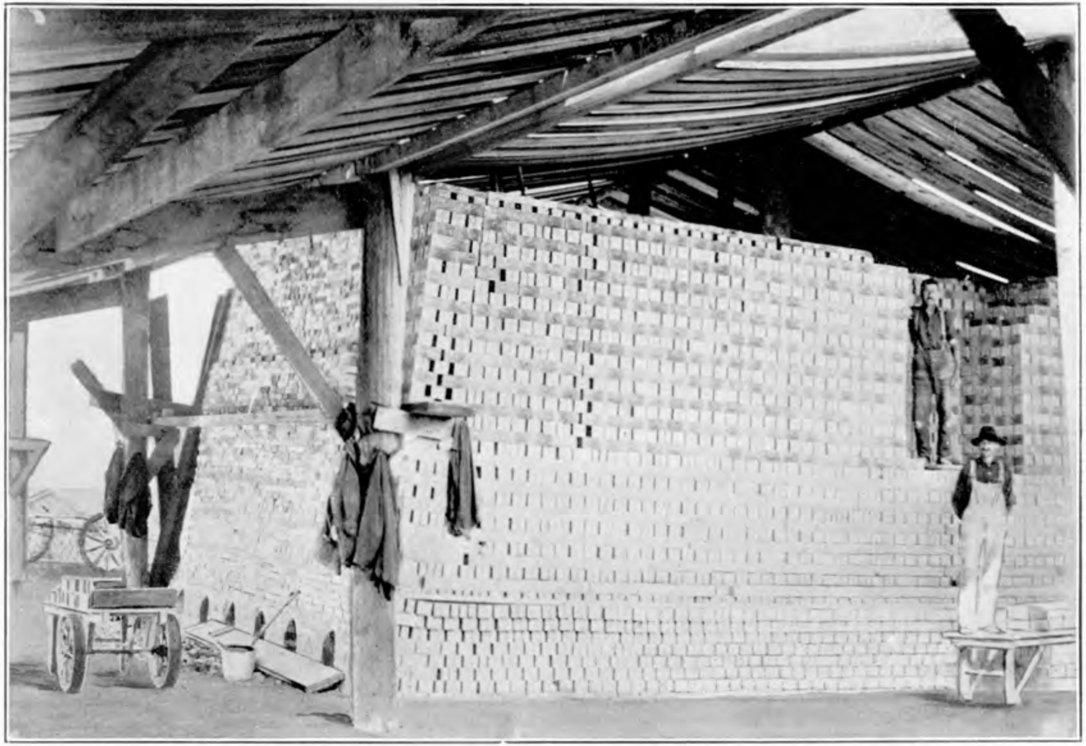
The clay contains such a high percentage of calcium carbonate that it is unsuitable for the manufacture of either vitrified or refractory wares.

RACINE.

Racine is situated on Lake Michigan in the southeastern part of the state and in the midst of the lacustrine clay deposits. Five brick plants have been established in this vicinity, four of which are at the present time actively engaged in the manufacture of brick.

One of the plants is equipped for making chemical sand brick out of lake sand and natural cement but owing to unfortunate circumstances the plant is now idle.

This plant is owned and operated by *W. H. Lathrop* and is known as the **Chemical Sand Brick Company.** The sand used in the manufacture of these brick occurs in abundance along the lake shore. It is mixed with natural cement and compacted by hydraulic pressure into any desired shape or size. The brick are variously colored with pigments provided for the purpose. The main objection to these brick is their weakness. The strength is so low that they frequently crack when subjected to very slight unequal stresses. They are also somewhat softer than the brick manufactured out of clay and when exposed to the atmosphere, weather more rapidly.



HILKER BROTHERS NORTH POINT BRICK YARD, RACINE.

ONE OF THE KILNS.

It is thought that a very desirable brick ought to be made out of this combination, if portland instead of natural cement were used.

The plants that are engaged in the manufacture of brick out of clay are owned and operated by *Bauman and Sons, F. N. Burdick, F. H. Hammerson and Sons,* and *The Hilker Brothers Brick Manufacturing Company.* The clay which occurs at all of the yards is essentially the same. In some places the red burning clay has a greater depth than at others. The percentages of quartz, calcite and limestone gravel are not the same in the clay from all the yards. However, in general, the clay is essentially the same and if burned with equal care the brick manufactured at one yard ought not to be superior to those at the others.

The Hilker Brother's Brick Manufacturing Company own and operate three yards in this locality. One of the yards, known as the North Point, is located about three miles north of the city near the North Point light house. The clay at this place is covered with sod and sand to a depth of one to three feet. Underneath the sand occurs from six to ten feet of purplish colored clay containing very few pebbles.

This clay is shoveled from the bank and conveyed in dump carts to vats in which it is tempered. About six wagon loads of sand is mixed with clay sufficient for manufacturing 12,000 brick. A small amount of fine coal is also mixed with the clay to assist in burning.

A Philadelphia tempering wheel operated by horse power, is used to mix the clay in the vats. The brick are moulded by hand, 4,000 brick being a day's work. The brick are dried in hacks on the yard and burned in scove kilns.

The clay bank at the Lake Shore yard consists of a stripping of about two and one-half feet of sod and sand, underneath which occurs from four to eight feet of laminated purple and blue clay and an unknown depth of blue clay which contains a considerable quantity of limestone gravel. The upper surface of blue clay is uneven and billowy, making the thickness of the workable clay uncertain. At this plant the clay is tempered in wooden pug mills operated by horse power. The brick are moulded by hand, dried in hacks on the yard, and burned in scove kilns.

At the Cedar Bend yard both common and repress brick are manufactured. The clay which is used at this yard has a somewhat different appearance from that which is mined at the other yards. The upper four to six feet has a greenish blue color and is streaked with reddish brown iron oxide which gives it much the appearance of a late alluvial deposit. Underneath this blue clay occurs two to three feet of sand, six inches of gravel, and forty feet of blue clay which is practically free from gravel of any kind.

The work at this yard is all done by hand. The brick are made and repressed by hand. All the brick are dried in hacks on the yard and burned in scove kilns. The repress brick are sold in four grades known as the (1) dark colored (2) medium colored (3) white colored and (4) hard.

The average annual output from these yards during the last three years has been in the neighborhood of three and a half million brick. The common brick sold in 1899 for $5.50 per M. kiln run and the repress for $10.00 per M.

The yard owned and operated by **F. H. Hammerson and Sons**, is located near the North Point yard of the Hilker Manufacturing Company and is worked on essentially the same plan. The clay is mixed with a small percentage of sand and tempered in wooden pug mills operated by horse power. The brick are moulded by hand, dried in hacks on the yard and burned in scove kilns.

At **Burdick's Yard** the workable clay has a thickness of from three to ten feet underneath which occurs about sixty feet of blue clay in which limestone gravel is abundant.

The clay which is being used is laminated and has a

THE SHAWANO BRICK YARD, SHAWANO.

purple and blue color. A small quantity of fine coal is mixed with the clay to assist in burning. The clay is mixed in a vat by means of a tempering wheel operated by horse power. The brick are moulded by hand, dried in hacks on the yard, and burned in scove kilns. It requires about eight days to burn the brick and a little over one-third of a cord of wood is consumed for each thousand brick burned.

The clay which occurs at **Bauman and Sons'** yard is similar to that at the previously described yards. The clay is mixed with a small percentage of sand and pugged with tempering wheels. The brick are moulded by hand, dried in hacks on the yard, and burned in scove kilns.

The average annual output of this yard for the last three years has been about one million brick. The kiln run brick sold in 1899 for $5.00 and $6.00 per M.

All the brick manufactured at these several plants are ordinarily made without sanding and are known as "slop brick." The clay is thrown into the moulds by hand and it is usually so soft that the workmen are badly bespattered with the mud which flies from the moulds.

In *general* it may be said that the method of manufacturing brick at these yards is very much behind the conception of the modern brick maker. Plants operated on a plan similar to these require the investment of very little capital. The brick, however, are moulded, dried and burned in such a manner that the cost of manufacture is above the average. With two moulders and six men to haul the clay from the pit and carry away the brick, the maximum output of a plant such as these is about 8,000 per day.

Under these conditions it is somewhat difficult for the Racine factories to compete in price with those in which improved machinery is used. It must be said, however, that the methods employed at the Racine yards insure a good strong brick, while the brick manufactured by some of the cheaper methods are not so reliable. The method of tempering clay with a wheel, although somewhat expensive is certainly very desirable. The brick which are made by hand from clay which is thus tempered are usually superior to those which are manufactured by the rapid method employed by some Chicago factories. However, it is believed that improved methods of drying, burning and moulding could be employed without materially lessening the quality of the brick.

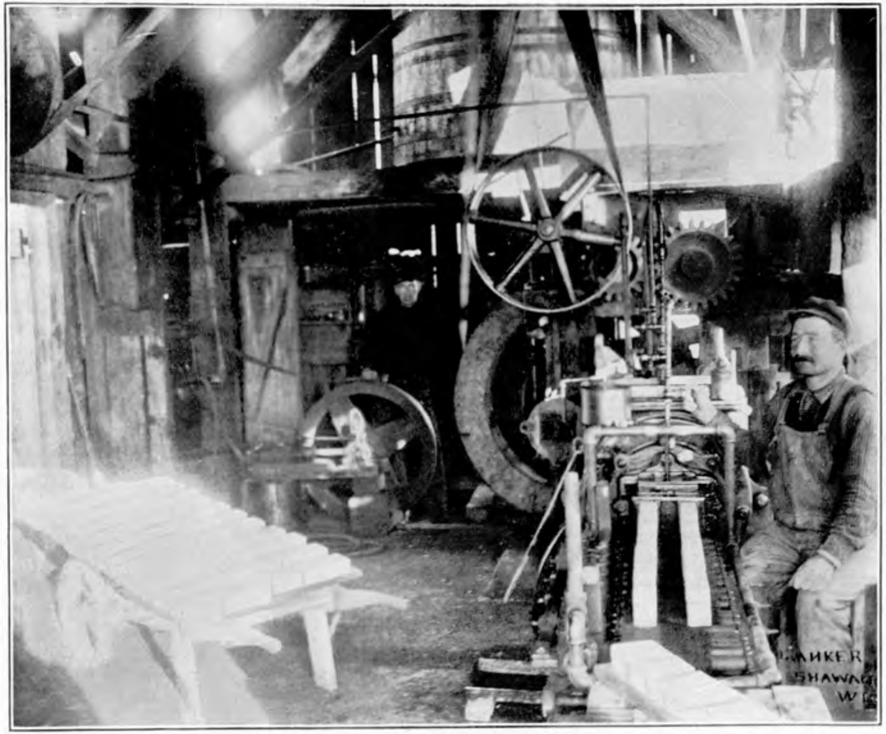
Laboratory Examination.—Samples of clay from the "West" and "Cedar Bend" yards of the Hilker Manufacturing Company were examined in the laboratory of the survey.

The clay from the West yard is hard and brittle when dry but very soft and plastic when wet. It slacks very readily, breaking down into very fine scales. Under the microscope the grains were found to average about .009 mm. in diameter, the largest not exceeding .029 of a mm. Numerous rhombic crystals of calcite were observed under the microscope. Many of the individuals were slightly discolored with iron oxide.

The blue clay from the Cedar Bend yard is hard and granular when dry but slacks readily in water, breaking down into a fine scaly mass. The clay has no distingnishing odor or taste and feels decidedly smooth when pressed between the fingers.

This clay is coarser grained than the preceding. The largest grains are .71 of a mm. in diameter. A greater number of the grains are .57 of a mm. in diameter, while the smaller grains range from .0058 and .0029 of a mm. in diameter. The individuals are mainly sub-angular in outline.

Quartz is a much more abundant constituent of this than the preceding clay. Calcite, iron oxide, chlorite, and kaolin are also present in undetermined proportions.



THE SHAWANO BRICK YARD, SHAWANO.

INTERIOR VIEW OF FACTORY.

SHAWANO.

Shawano is situated in the south central part of Shawano county near the northern limit of the lucustrine clay region. The **Shawano Brick Yard** which is owned and operated by *Chas. Larson*, is located on the West bank of the Wolf River in the south part of the city. The clay at this place is covered with two feet of sand which is stripped. Underneath the sand occurs from two to four feet of red burning clay, which is also removed; eight to ten feet of red clay which burns white; and six to eight feet of blue clay which burns white. Below this there is an indefinite thickness of sand.

All of the clay is laminated. The clay is only worked to the water level which is about ten feet below the red burning clay.

The clay is soaked in vats for about fifteen hours and then mixed in a pug mill. The brick are made in a stiff mud machine equipped with an end cut-off, dried in hacks on the yard and on pallets under sheds, and burned in permanent round and square up draft kilns. Two of the kilns were designed and built by Mr. Larson, the owner of the yard. The brick have a white or cream color when properly burned. The average annual output of the yard during the last three years has been from 500,000 to 600,000. The brick sold in 1899 for about $5.50 per M. kiln run.

Laboratory Examination.—The clay occurs in alternating dark chocolate brown and light pinkish colored layers. The pink colored clay slacks very readily in water breaking down into a very fine plastic mass. The largest grains observed by aid of the microscope were about .1 mm. in diameter. Most of the grains are under .014 mm. in diameter, a major part of the clay being composed of grains having a diameter of less than .0058 mm. Many of the small individuals are prismatic in shape and all except those having crystal outlines are irregular and angular.

The clay contains numerous dark patches caused by the iron oxide which is present as a staining agent. The rhombic forms are evidently either calcite or dolomite. The number of quartz grains which were distinguishable was very small.

The layers of the dark chocolate colored clay consist of grains which are much smaller than those in the layers of pink clay above described. Nine-tenths of this clay consists of grains which are under .0029 of a mm. in diameter. Many of the individuals are somewhat prismatic in shape, although the majority have irregular outlines. The clay undoubtedly contains a high percentage of calcite, although the exceptional fineness of the grains prevented a ready determination. The clay is stained throughout with iron oxide. Clusters of individuals were abundant under the field of the microscope.

This clay is unsuitable for the manufacture of either refractory or vitrified wares although well adapted to the manufacture of common brick.

SHEBOYGAN.

The clay which is being exploited at Sheboygan is also a part of the lacustrine deposit and the brick which are manufactured are cream colored.

Three plants are located at this place and are operated by the Sheboygan Brick and Tile Company, the Zurhide Brick Manufacturing Company, and August Zimbal and Son.

The **Sheboygan Brick and Tile Company's** yard is located in the west part of the city. The clay has a total thickness above the water level of forty-two feet. The upper portion of the bank is known as the red clay and the lower as the blue. The upper four or five feet of the bank is stripped, owing to the limestone gravel which it contains. Underneath this the clay is essentially free from pebbles with the exception of a layer twelve or fifteen inches in

THE SHAWANO BRICK YARD, SHAWANO.

SQUARE KILN.

thickness near the bottom. Thirty loads of lake sand is mixed with the clay for every 100,000 brick. The clay is passed through a crusher and the brick are moulded in a J. W. Penfield stiff mud machine having a side cut-off. The brick are dried mainly in hacks on the yard and burned in scove kilns. The capacity of the dry yard is 140,000 and the kiln capacity is 800,000. It requires on an average of ten days to burn the brick and about one-half cord of soft wood is consumed for each thousand brick burned. The yard is equipped with a hand re-press which is used in the manufacture of select or veneer brick.

A layer of fine sand one foot in thickness which occurs in the middle of the bank is used for manufacturing scouring brick. In 1899 between two and three thousand scouring brick were made and sold.

Laboratory Examination.—This clay was examined in the laboratory of the Survey and found to be essentially the same as all the other samples of lacustrine clay examined. Some of the layers are hard and others soft and crumbly. The clay slacks readily in water breaking down into a fine plastic mass. The microscopic examination of the blue clay shows that it consists of grains ranging from .14 to .001 mm. and less in diameter. The grains average from .025 to .014 mm. in diameter. The very small grains, .009 mm. and less in diameter, occur in the greatest numbers although they constitute a lesser portion of the clay. The outlines of the individuals are fairly well rounded. Many of the grains have a dirty brown color owing to staining by iron oxide.

The reddish colored clay consists of a mass of small individuals from .0029 to .0014 of a mm. in diameter, in which are imbedded larger grains ranging from .10 to .04 mm. in diameter. The larger grains are somewhat discolored with iron oxide and their identity is thereby obscured. The other grains are too small to recognize distinguishing characteristics. The chemical composition of the red clay is given in table I of the Appendix.

The **Zurhide Brick Manufacturing Company** is working a thickness of about thirty feet of clay. About two feet of black, loamy clay at the top of the bank, underneath which occurs fifteen feet of red clay and an unknown depth of blue clay, fifteen feet of which is now worked. An occasional limestone pebble is found throughout the bank.

A small quantity of sand is mixed with the clay, after which it is passed through a Penfield disintegrator and tempered in a Penfield pug mill. The brick are made in a Penfield and Sons' stiff mud machine, dried in hacks on the yard and burned in scove kilns. The capacity of the dry yard is about 100,000 while the kiln sheds hold in the neighborhood of 900,000.

This yard was opened in 1896, and has been operated each year since that time. The output in 1898 was over 1,100,000 brick. The brick sold in 1899 for about $6.50 per M. kiln run.

The clay bank which is worked by **August Zimbal and Son** consists of a stripping of from three to four feet of sand and gravel, six feet of red clay, forty feet of blue clay and an unknown thickness of clay carrying large quantities of gravel and numerous boulders. The bank which is worked to a depth of forty feet contains streaks and beds of sand, one of which is about three feet in thickness. Very few pebbles are found in the blue clay which is now being worked although an occasional large boulder is encountered.

The clay is conveyed from the bank to the machine on cars run by a steam hoist. The clay is mixed with about one-seventh or one-eighth lake sand and tempered in a Penfield pug mill. From the pug mill the clay is carried on a belt conveyor to a Penfield stiff mud machine in which the brick are moulded. The brick are dried in hacks on the yard and burned in scove kilns. The kiln capacity is about 1,400,000. The brick are burned eight or nine days on an average and about one-half a cord of wood is consumed for every thousand brick burned.

AUGUST ZIMBAL AND SONS' BRICK YARD, SHEBOYGAN.

The select brick are repressed by hand, a Drake machine being used for this purpose.

The brick have either a white or cream color when properly burned. The sand which is sprinkled on the brick when they are removed to the yard, is very calcareous. On account of this it frequently fuses in the kiln causing the brick to adhere to one another.

This yard was opened in 1888 and has been operated each year since that time. In 1898 the output of the plant was over one million brick. The average price in 1899 was $6.50 per M. kiln run.

Laboratory Examination. — The sample examined in the laboratory of the Survey was moderately hard when dry and very plastic when wet. This clay slacks quickly, breaking down into very small flakes.

Under the microscope it was observed that the individuals have a tendency to cluster. Most of the grains are less than .001 mm. in diameter, although a considerable number have diameters of .014 mm. The individuals are slightly stained with iron oxide. The outlines of the larger grains are somewhat rounded or oval. The identification of the mineral constituents was very uncertain.

Another sample of clay from this yard which was examined, differed from the previous one mainly in the higher percentage of iron oxide staining and the greater abundance of grains that have a diameter of over .029 mm.

The third sample of clay examined is known as the blue clay. This sample slacked readily, breaking down into thin concentric scales, many of which were so fine they floated on the surface of the water. The clay is soft and plastic when wet.

The microscopic examination showed that the largest grains were under .029 mm. in diameter. Most of the individuals are less than .014 mm. in diameter. The tendency for the very minute individuals to cluster was observed again in this sample. The individuals are rounded to subangular in outline with the exception of certain rhombic plates of calcite. The chemical composition of the clay from A. Zimball and Sons' yard is given in table I of the appendix.

All of the clay which occurs in the vicinity of Sheboygan is calcareous and unsuitable for the manufacture of either vitrified or refractory wares, although it is admirably adapted to the manufacture of building brick and similar unvitrified wares.

SHEBOYGAN FALLS.

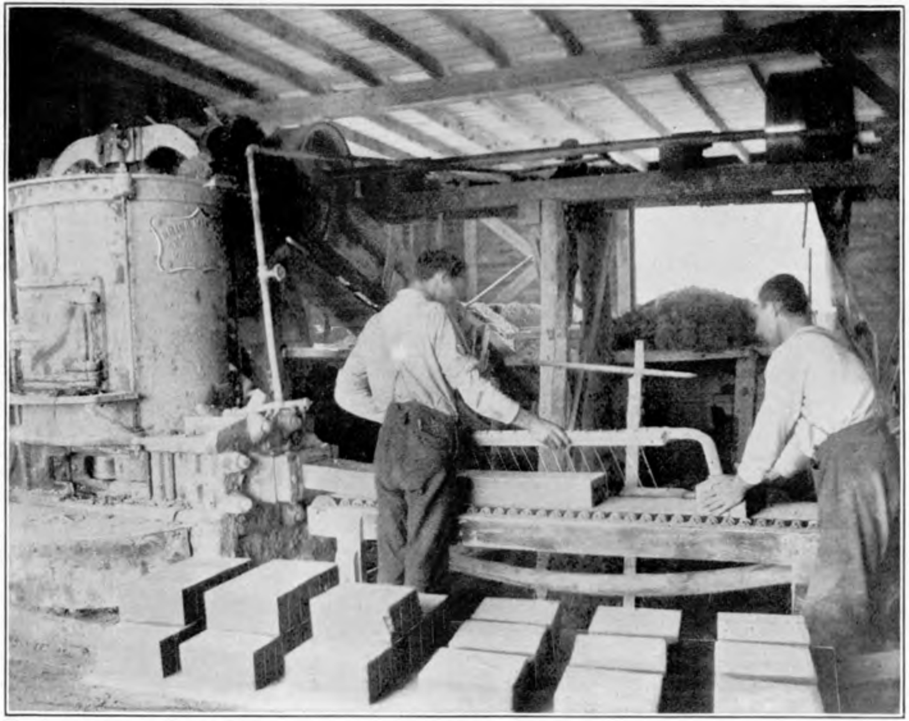
The clay which occurs at Sheboygan Falls is very similar to that which is being mined at Sheboygan. The only yard operated at this place is owned by **Jacob Ramaker.** Red, yellow and blue clays are mingled together in the clay bank in a very irregular manner. The contorted character of the beds gives one the impression that they have been folded through some kind of pressure.

The clay is tempered in an ordinary wooden pug mill operated by horse power. The brick are moulded by hand, dried in hacks on the yard, and burned in scove kilns. The brick are moulded without sand and are known as "slop brick." It requires about ten days to burn the brick and three-fourths of a cord of wood is consumed for each thousand brick burned. This yard was opened in 1897 and has been operated each year since that time. During the last three years the average annual output has been about 700,000.

The brick were sold in 1899 for about $6.00 per M. kiln run.

SHIOCTON.

Shiocton is located in the western part of Outagamie County on the Green Bay and Western Railroad. The Wolf river flows through this place and has cut a channel of some depth and breadth through the underlying deposits. At numerous places along the river channel clay deposits are exposed. This clay was tested with an auger at Shiocton and several other places for a distance of six



AUGUST ZIMBAL AND SONS' BRICK YARD, SHEBOYGAN.

BRICK MACHINE IN OPERATION.

miles north. Everywhere the clay was over ten feet in thickness and usually covered with six feet of coarse yellow sand. Well borings at Shiocton show that the clay has a depth of twenty-five feet down to quick sand. Below this layer of sand the clay continues to a depth of sixty or more feet.

The manner in which the clay occurs and its relation to the river are shown in the accompanying cross sections taken several miles north of Shiocton.

The clay has a general pinkish color, is exceedingly plastic at a depth of three feet below the sand and apparently free from gravel. It occurs in thin layers which appear to be very similar in composition.

Laboratory Examination.—The clay occurring on the farm of *W. D. Jordon* about two and a half miles north of the village was examined in the Survey laboratory. The clay is exceedingly fine grained and free from coarse sand. It slacks readily breaking down into fine flakes. The microscopic examination shows that the grains vary in size from .0086 to less than .0029 mm. in diameter. A few large grains .04 mm. to .29 mm. in diameter were observed. The grains in general are roundish, sub-angular and rhombic in outline.

The grains are so small that their identity is largely obscured. The rhombic sections are probably calcite and the faint staining of the grains is probably due to iron oxide. The chemical composition of this clay is given in table I of the appendix.

The sand which occurs abundantly in this region consists of grains ranging from 0.1 to 0.5 mm. in diameter with an average of 0.3 mm. The sand is mainly quartz although occasional grains of calcite were observed. The grains were very well rounded in both samples examined.

This clay occurs in vast quantities in this region. It is easily mined, close to the railroad and well adapted to the manufacture of brick, drain tile, and all wares where a vitrified or refractory body is not required. The clay will burn white or cream color and ought to make excellent building brick or hollow building blocks.

STURGEON BAY.

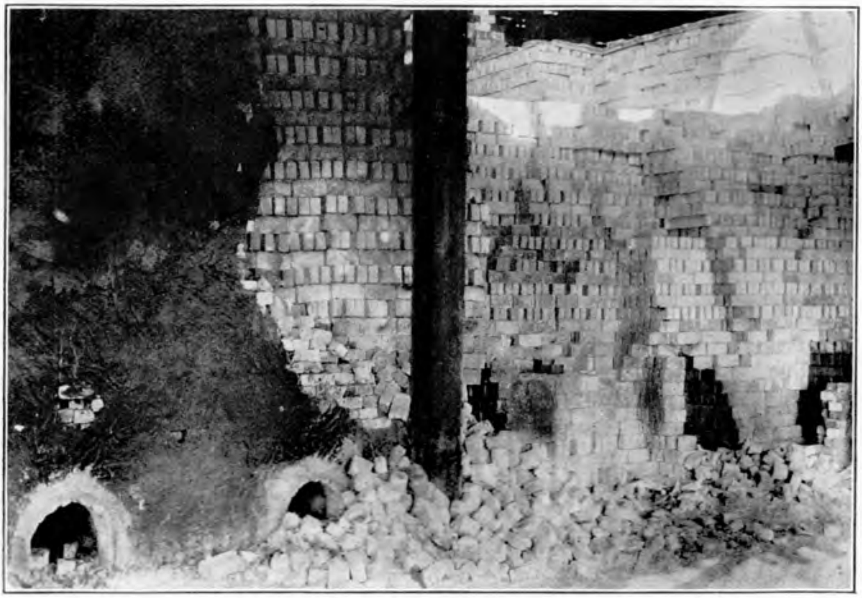
Sturgeon Bay is situated in Door County and is in the midst of the lacustrine clays. The only plant in this vicinity is located about two miles southeast of that portion of the city formerly known as Sawyer and is owned and operated by **Simon and Kessler.**

The clay bank consists of a stripping of about one foot of soil, underneath which occurs one foot and a half of heavy red clay, containing an occasional pebble of limestone or other rock, and an indefinite thickness of clay which is so filled with limestone gravel that it is worthless. The clay is plowed and allowed to weather in the field, after which it is soaked in a vat. The brick are moulded in a Quaker soft mud machine, dried on pallets under sheds, and burned in scove kilns. The clay naturally burns red but in order to impart a more brilliant color red ochre is mixed with the moulding sand. It requires about eight days to burn the brick and one-half cord of wood is consumed for each thousand brick burned.

This yard was opened in 1884 and has been operated each year since, with the exception of 1897. During the last two years the average annual output has been about 400,000 brick. The brick were sold in 1899 for about $4.50 per M. kiln run.

UNION GROVE.

Union Grove is located in the southern part of Racine County near the western border of the lacustrine clay deposits. One plant is located at this place which is owned and operated by **Michael Niesen.** The clay bank consists of 7½ feet of mixed red and blue clay, which burns red, and three feet of blue clay, one foot of which is free from limestone pebbles and burns white. The mixed clay contains



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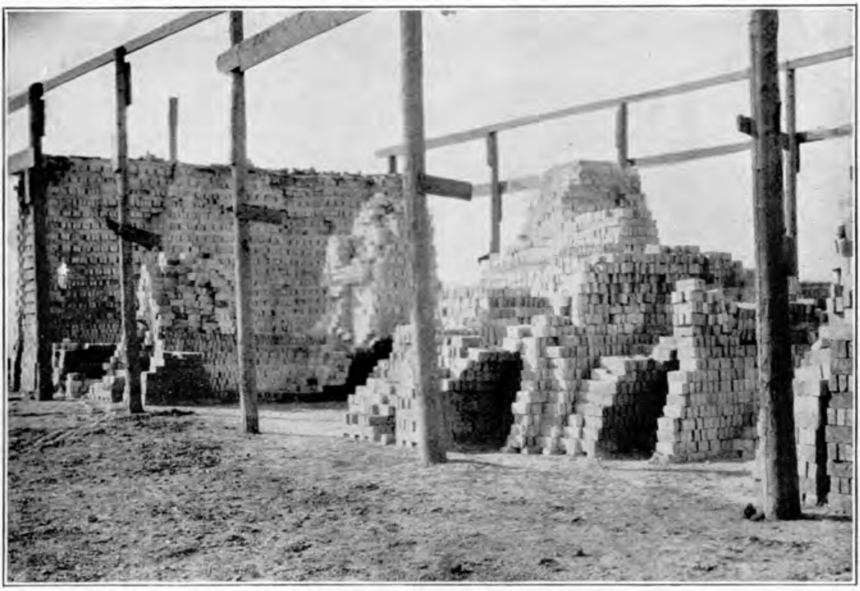

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AUGUST ZIMBAL AND SONS' BRICK YARD, SHEBOYGAN.

INTERIOR VIEWS OF SCOVE KILNS.

pockets of limestone gravel which must be avoided in working the bank. The clay is passed through an Anderson disintegrator and the brick and tile are moulded in a Brewer No. 5 brick and tile machine. The brick and tile are dried under sheds without artificial heat and burned in square down draft kilns. The brick and tile have a light red, streaked, or cream color.

The average annual output during the last three years has been about 50,000 brick and twenty kilns of tile.

WAUPACA.

Waupaca is situated in the southwestern part of Waupaca County near the western limit of the lacustrine clay area. The brick yard, which is owned by **W. J. Chamberlin** and operated by **W. E. Chamberlin,** is located about a mile and a half southeast of the city. The workable clay is covered with a stripping of from three to thirty feet of boulder clay. The clay which is mined has a depth of from eight to ten feet above the level of the underground water. Between the stripping and the clay which is being worked there is a layer of sand about two and one-half feet in thickness. The clay consists of alternate reddish brown and yellow layers which are separated by thin laminae of sand. The brick are made in a Henry Martin soft mud machine, dried on pallets under sheds, and burned in scove kilns. The capacity of the pallet sheds is about 80,000 and the kiln capacity is nearly 700,000.

The machinery at this plant is run by water power.

The brick have a light pink color, which is intensified by using a moulding sand which burns red. The small lumps of clay which show through the brick after they are burned indicate that the clay is not thoroughly mixed or tempered before being moulded.

The average annual output of this yard for the last three years has been from 150,000 to 250,000. In 1899 the brick sold at $6.00 per M. kiln run.

WAUWAUTOSA.

See Milwaukee.

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VIEWS OF TYPICAL ESTUARINE CLAY BANKS.

CHAPTER VIII.

ESTUARINE DEPOSITS, CONTIGUOUS TO THE LACUSTRINE DEPOSITS.

The clays which are classified under this head include all those clays of the eastern portion of the state, underlain by limestone and modified by glacial action, which have not been included in the lacustrine deposits previously discussed. More strictly speaking they are the estuarine deposits formed at the same time and in connection with the lake deposits. They resemble so closely the lacustrine clays that they might consistently be classified and discussed as a part of those deposits. They are mapped together as shown in the map, plate I.

These clays are mainly of alluvial and glacial origin or both and do not differ essentially, either chemically or physically, from the lacustrine clays. They are mainly composed of limestone detritus, powdered and pulverized by the grinding action of the glaciers and rivers and deposited in quiet water. It is thought that most of the clays which have been examined in this region were formed contemporaneously with the lacustrine deposits shown on the general map. A portion of this area is underlain by sandstone but the alluvial deposits there formed have been modified and made calcareous by the addition of detritus transported from contiguous limestone areas.

The clays of this region will be considered by localities and each manufacturing plant will be treated in as much detail as space permits.

BARABOO.

Baraboo is located in Sauk county near the western limit of the alluvial clay area as outlined on the accompanying map. The clays occurring at this place are near the Baraboo river, and are often incorrectly spoken of as Loess deposits.

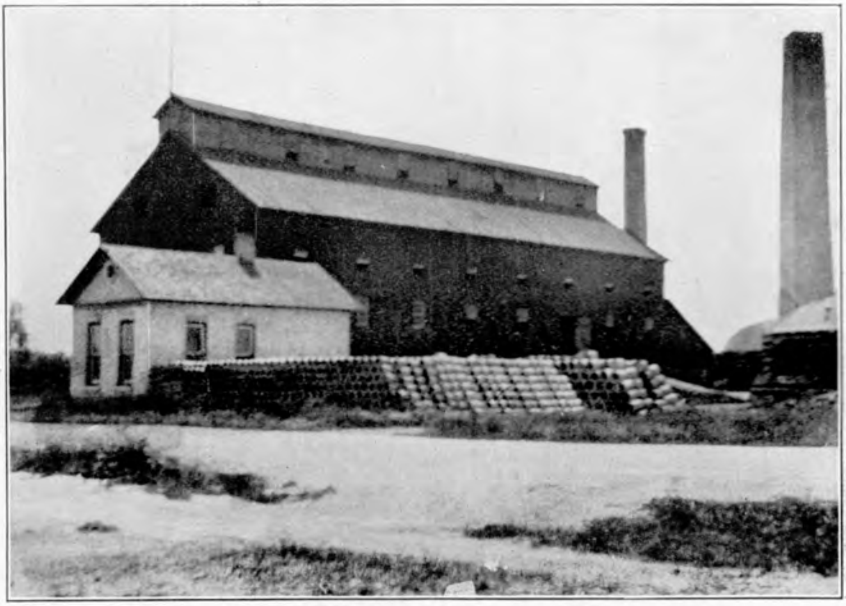
The only brick yard in this vicinity is owned and operated by **John Paddock.** It was opened twenty-one years ago and has been operated each year since that time.

The bank from which the clay is obtained consists of from six to twelve feet of gravel and boulder clay, all of which is stripped. Underneath this occurs one foot of red burning clay, two feet of gray sandy clay impregnated with iron oxide, one and one-half to two and one-half feet of quick sand, and thirty feet of blue clay which rests upon sandstone. All of the clay, with the exception of one foot at the top, burns a white or cream color. The clay is taken from the bank in the fall and weathered over winter. When used it is mixed with a tempering wheel operated by horse power. The brick are moulded in a Quaker machine, dried in hacks on the yard, and burned in scove kilns. It requires about seven days to burn the brick and about one-third cord of wood is consumed for every thousand brick burned.

During the last three years the average annnal output of the yard has been about 150,000 brick. They sold at the yard in 1899 for about $8.00 per M. kiln run.

BEAVER DAM.

Beaver Dam is situated in Dodge county near the center of the estuarine clay area. One plant, known as the **Beaver Dam Brick Works** and owned and operated by *John Hutchinson,* is located at this place. The clay bank consists of seven feet of blue clay, streaked with iron oxide, underneath which occurs two feet of quicksand and an unknown thickness of gravel. The clay is mined from the



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BRICK AND TILE FACTORIES.

FIGURE 1.—THE BURLINGTON BRICK AND TILE CO., BURLINGTON.
FIGURE 2.—THE NORTH CAPE BRICK AND TILE MANUFACTURING CO., NORTH CAPE.

bank in the fall and weathered over winter. When used it is mixed with about one-seventh sand. The clay is tempered in a vat with a tempering wheel. The brick are manufactured by hand, dried in hacks on the yard, and burned in permanent up draft kilns. The brick burn red owing to the very considerable percentage of iron oxide in the clay.

The average annual output of the yard during the last three years has been about 200,000 brick. They sold at the yard in 1899 for $6.00 to $6.50 per M. kiln run.

About two and one-half miles east of Beaver Dam is located a small yard operated by **Mr. Schultz.** The brick at this yard are made by hand, dried in hacks on the yard, and burned in a temporary up draft kiln.

BURLINGTON.

Burlington is situated in the southwestern part of Racine county on the Fox river,[1] and according to the former Geological Survey, is outside of the lacustrine clay area. In this report it is considered as a part of the estuarine deposits.

The Burlington Brick and Tile Company, of which *William Meadows* is manager, was opened in 1887, and has been operated each year since that time, from the first of April to the 15th of December. The company manufactures drain tile and common brick.

The clay has an average thickness, at this place, of fifteen feet and is covered with about two feet of soil stripping, in which occurs pockets of gravel. The upper twelve feet of clay is separated from that below by a twelve inch bed of sand. The clay which occurs at the bottom of the bank, underneath the sand, is exceedingly tough. An occasional limestone pebble occurs in the body of the clay. Below the surface stripping the clay is mined as it occurs

[1] This is a different river from the Fox river mentioned before. This flows south while the other Fox river flows northeast.

in the bank and mixed with sand in the proportions of one part of sand to four of clay. The mixture is soaked in a vat over night and in the morning it is passed through a Potts' disintegrator. From the disintegrator the clay is carried by means of a belt conveyor to a pug mill connected with a No. 9–A Brewer machine. The brick machine is run by a thirty horse power engine and has a capacity of 30,000 brick per day. The brick and tile shed is a four story building constructed in a substantial manner. The brick and tile are mainly air dried, although the shed is provided with about 6,000 feet of gas pipe through which live or exhaust steam can be passed to hasten the drying when necessary.

The tile are burned in round down draft kilns and the brick in up draft scove kilns. The brick and tile are white or cream colored when properly burned. When underburned or mixed with too great a quantity of red burning clay they frequently have a reddish color.

During the last three years the company has manufactured annually about a million brick, and from 40 to 60 kilns of drain tile. The product is shipped west as far as central Iowa and east as far as Chicago. The market includes portions of Minnesota, Illinois, Michigan, Iowa, and southern Wisconsin.

Laboratory Examination.—The clay which occurs near the top has a reddish color and that below is grayish blue.

The red clay is moderately hard when dry and very plastic when wet. It has no distinguishing taste or odor but gives evidence of containing a fine grit when tested between the teeth. The clay slacks quickly, breaking down into small thin scales. The largest grains observed by aid of the microscope were about .033 of a mm. in diameter. Grains having a diameter of .014 of a mm. are scattered promiscuously among the multitudes of small individuals which are .003 of a mm. and less in diameter. The large grains are fairly well rounded, but the small ones are unequi-dimensional and angular in outline.

Individuals of quartz, calcite, and kaolin were observed in the sample examined.

The blue clay occurs in layers of considerable thickness. It is moderately hard and brittle when dry and very soft and plastic when wet. It has no distinguishing odor or taste and very little grit can be detected when tested between the teeth.

The clay has a light drab color with a faint tinge of yellow. Small, white, limy-looking spots occur between the laminae. When wet the clay has a yellowish tint. It slacks very readily, breaking down into thin scales, somewhat larger than usual in clays of this character. Under the microscope the grains are found to be exceedingly fine. None were observed that had a diameter greater than .014 of a mm. The average size was about .003 of a mm., although there were myriads less than .0014 mm. in diameter. The large individals were better rounded than the small ones.

The general appearance of this clay indicates the presence of calcite and quartz, although the individuals are so small that it is difficult to positively identify them. The chemical composition of the clay is given in table I of the Appendix.

The clay is calcareous and is unsuitable for the manufacture of either vitrified or refractory wares. The clay might, however, be used to advantage in the manufacture of flower pots, cheap cuspidors, etc.

CECIL.

Cecil is located in the western part of Shawano county on the Chicago and Northwestern railroad. The only brick yard near this place is located five miles from the village of Cecil and one and one-half miles from Underhill, and is owned and operated by **Albert Heise.** The yard is situated on the east side of the Oconto river and the clay is undoubtedly of estuarine origin.

Two kinds of clay are obtained at this place. That which occurs in the bank farthest from the river has a thickness of about five feet. Below this depth the clay is unworked on account of the large quantities of limestone gravel which it contains. The raw clay has a reddish brown color and burns a white or cream color. Care must be continually exercised in removing the surface clay not to mix with it that which contains limestone gravel underneath. A greater part of the second bank of clay is thinly laminated and consists of alternating reddish brown and bluish gray layers. Above the laminated clay occurs a thickness of from one to two feet of tough, jointed, red clay which burns red. Five feet below the surface the laminated clay changes to more of a blue color and is there known as the blue clay. This bank has been tested to a depth of thirty feet without reaching bottom or encountering limestone gravel.

The yard is equipped with a J. C. Steel and Sons' stiff mud machine with side cut off and re-press. At the present time the machine is not being used and the brick are made by hand. When the brick are made by hand the clay is soaked over night in vats and tempered in horse power pug mills. The brick are dried in hacks on the yard and in pallets under sheds and burned in scove kilns having what are known as "dog ovens." It requires about seven days to burn the brick and one-half cord of mixed wood is consumed for each thousand brick burned. In 1899, 50,000 brick were manufactured, all of which were sold at the yard, mainly to farmers.

A large part of the brick which are manufactured are red, although the demand is mainly for white or cream colored brick. It is thought that the blue clay, which underlies the red burning clay in the bank near the river, will burn a white or cream color if mined at a sufficient depth and used alone.

DENOON.

Denoon is located in the southeastern part of Waukesha county, between the Mukwonago River and Muskego Lake. It is about seven miles west of the lacustrine clay area as mapped by the former Geological Survey. The clay at this place was probably deposited either by the neighboring river or lake during the glacial period. It is possible, however, that this deposit may be a part of the general lacustrine clay area.

The Denoon Brick and Tile Company, which is owned by *A. Guhr, Sr.,* and operated by his son, is located one mile north of Denoon post office and one mile west of the southern end of Muskego Lake. The yard was opened in 1887 and has been operated almost continuously ever since. The clay bank consists of a stripping of sod, four feet of red burning clay, and an unknown depth of blue clay which burns white.

For manufacturing brick the clay is mixed with sand in the proportion of three parts of clay to two of sand. For the manufacture of tile the clay and sand are mixed in the proportions of four parts of clay to one of sand. The clay is transferred from the bank to a vat where it is soaked over night. From the vat it is carried on a belt conveyor to a crusher and from thence by means of a chute into a No. 9 A Brewer brick and tile machine. The plant has a daily capacity of 6,000 to 15,000 three inch tile or 25,000 brick. All sizes of tile from three to twelve inch are manufactured. It requires eight men to operate the plant at its full capacity.

The brick and tile are dried on pallets under sheds and burned in three square down draft kilns, having a total capacity of about 78,000 three inch tile. The brick and tile which were examined in the yard were first class in all respects.

The yard is located so far from any railroad that it can probably never be developed beyond a capacity to supply the local demand for brick and drain tile. The clay is calcareous and unsuitable for the manufacture of either vitrified or refractory wares.

EDGERTON.

Edgerton is located in the northern part of Rock county on the Chicago, Milwaukee and St. Paul railroad. The clay which occurs here is among the better quality of calcium clays of the region under discussion. The bank from which most of the clay has been obtained consists of about three to three and one-half feet of stripping, two to two and one-half feet of yellow clay, and twelve feet of grayish blue clay. There is very little gravel in the clay, although a small boulder is occasionally found.

The Edgerton Brick Yard, which is owned and operated by *Royal Parr,* is the only brick plant located at this place. Several potteries have been established here at different times, but at present only one is in operation. This is known as the Edgerton Art Clay Works and is owned by L. H. Towne.

The Edgerton Brick Yard, is located on the south side of the railroad and within the city limits. The clay is mined with a pick and shovel and conveyed from the bank to the plant by means of cable cars. A small quantity of sand is mixed with the clay, after which it is passed into a pug mill and from thence to a Penfield stiff mud machine. Each brick is perforated with two holes and all are handled with forks. The brick are dried in hacks on the yard and burned in scove kilns. Mixed wood and coal are used for fuel and it costs about $1.50 per M. for burning.

The Edgerton brick yard was opened in 1881 and has been operated each year since that time with the exception of 1886. The brick were sold at the yard in 1899 for $5.00 to $7.00 per M.

The Edgerton Art Clay Works, owned by *L. H. Towne,* is engaged in the manufacture of terra cotta art ware. The clay is obtained mainly from the Edgerton brick yard and from the clay bank of the Springfield Brick and Tile Company of Walworth county. The white burning Edgerton clay and the red burning Springfield clay are mixed in definite weighed proportions to produce the desired tints. The wares are either moulded or turned and are burned in a Wilke kiln.

The terra cotta art ware from this factory has found a good market in Wisconsin and neighboring states.

The Pauline Pottery Company, managed by *Mrs. Pauline Jacobus,* was established in Edgerton in 1888. The products of this factory were porous cells for electric batteries and underglaze art ware. Ewers, vases, flower jars, bon bon boxes, candlesticks, lamp stands, and other fancy designs were produced. The wares were made in imitation of the ordinary Japanese Kioto and modern Italian majolica wares.

Owing to the business depression from 1893–95, the company was obliged to shut down. The plant is still idle. However, the pottery manufactured by this company was of such excellence that it demonstrated the feasibility of establishing other factories in Wisconsin.

ELKHORN.

Elkhorn is located in the center of Walworth county on the Chicago, Milwaukee and St. Paul Railroad and about twenty-five miles west of the lacustrine clay area.

The Elkhorn Brick and Tile Works, which are owned and operated by *Sprague Brothers,* are located on the Delavan road, about one-half mile west of the city. The clay bank is a mixture of sand and clay, having a variable thickness of from six to twelve feet. Occasional pockets of gravel containing limestone pebbles occur near the top of the bank. The gravel, however, does not occur in any abundance within the clay itself. In places the clay contains streaks, bands, and concretions of iron oxide, which give it a mottled, bluish brown color. In other places the color is blue streaked with yellow.

The clay is mixed with water on the floor before being passed through the crusher. From the crusher it is removed on a belt conveyer to a pug mill connected with a stiff mud machine in which both brick and tile are manufactured. The tile are dried in a three story building provided with iron pipes for artificial heating. The brick are dried on pallets under sheds. The brick and tile are both burned in round down draft kilns, of which there are three. Soft coal is the main fuel used for burning. In some instances four tiers of tile are stacked on the bottom of the kiln and brick are piled above.

The brick and tile, as a rule, have a mottled red and white color which is probably due to the imperfect mixing of the red and white burning clays. The tile are somewhat rough on the surface and are more or less injured by the limestone pebbles which are not completely removed from the clay.

Besides brick and drain tile the company have manufactured a considerable quantity of sidewalk blocks, $8\frac{3}{4}$ inches square by $2\frac{1}{2}$ inches thick. From the appearance of the blocks which have been used in the sidewalks of Elkhorn one would judge that they are not entirely satisfactory. The blocks are not vitrified and are consequently too soft to wear well. The clay is unsuitable for the manufacture of either refractory or vitrified wares.

ENDEAVOR.

Endeavor is located near the central part of Columbia county on the Wisconsin Central railroad. The clay which is mined at this place occurs near the Fox River and is very similar to that which occurs in other parts of the valley. The plant was erected in 1890 but has only been operated part of the time since. The plant is owned by the **Christian Endeavor Academy**, R. L. Cheney, President, and is operated by the students of the Academy.

The clay has a total thickness of forty-five feet. The upper three feet is a red granular clay, containing an occasional pocket of limestone gravel and covered with an irregular thickness of sand. This clay burns red but at present it is not used on account of the difficulty experienced in drying the brick made therefrom. The clay which occurs underneath the red is known as the blue and burns white. The clay is mined with pick and shovel, hauled on dump carts to the factory, and mixed on a board platform. The brick are moulded in a Sword machine, operated by horse power, dried on pallets under canvas and in hacks on the yard, and burned in scove kilns. The output in 1899 was about 100,000, and the market price that year was about $6.00 per M.

During the current year the Academy expects to install new machinery, erect new kilns, and improve the plant generally. When these needed improvements are made, no difficulty ought to be experienced in manufacturing first class building brick.

Laboratory Examination.—The clay is soft and crumbly when dry and very plastic when wet. It contains some sand in moderately coarse grains.

The chemical analyses which are given in table I of the Appendix show that both the red and blue clays contain high percentages of calcium and magnesium carbonate. A moderate quantity of silica is present, mainly in the form of quartz. The aluminum is low.

The clay is very similar to that which is being worked in the Green Bay and De Pere region.

FORT ATKINSON.

Fort Atkinson is located in the south central part of Jefferson County on the Chicago and Northwestern railroad. The only brick yard at this place is that of the **Fort Atkinson Brick Manufacturing Company**, which is owned and operated by *W. P. Haumerson and Son.* The yard was opened in 1865 or 1866 and purchased by Mr. Haumerson in 1886, since which time it has been operated each year. Common brick and drain tile are manufactured.

The clay, which has a general blue color, varies in depth in different parts of the bank. It is weathered on the yard before being used. Sand is mixed with the clay in the proportions of one of sand to four of clay. The clay is then pugged in vats by means of tempering wheels operated by steam power. During the last three years the brick have all been made by hand, dried in pallets under sheds, and burned in scove kilns. Coal and wood are mixed for fuel and it costs about $1.10 per M. to burn the brick.

During the last three years the average annual output of the yard has been in the neighborhood of one million brick. The average price of the brick in 1899 was $6.00 per M. kiln run.

Laboratory Examination.—The clay which is now being mined by this company was examined in the laboratory of the Survey. It is a laminated alluvial deposit, which is hard and brittle when dry but very soft and plastic when wet. It slacks readily in water, breaking down into a coarse pulverulent or scaly mass. The microscopic examination shows that a greater part of the clay consists of grains that are under .0058 mm. in diameter. The largest grains do not exceed .03 mm. in diameter. The smaller grains are irregular and angular in outline, although the larger sized individuals are somewhat rounded.

Quartz and rhombic crystals of calcite, as well as stainings of iron oxide, are abundant. The two samples of clay examined appear essentially the same under the microscope, with the exception that one is finer grained than the other. Both contain abundant calcite grains, which is evidence that the clay is high in lime. The chemical composition of the clay is given in the table of analyses in the Appendix. The clay is unsuitable for the manufacture of either vitrified or refractory wares.

GILLETT.

Gillett is located in the west central part of Oconto County on the Chicago and Northwestern Railroad. The yard of the **Gillett Brick Manufacturing Company,** which is owned by *Mrs. H. Truman,* of Manitowoc, is located about half a mile east of the depot.

The clay bank has a thickness of about fifteen feet. The upper portion, consisting of from three to eight feet of red clay, is worthless on account of the quantity of limestone gravel which it contains. Underneath this occurs four feet of coarse yellow sand and from six to eight feet of blue clay. The upper portion of the blue clay has a yellowish tint caused by the oxidation of the iron. The blue clay contains an occasional limestone pebble, but otherwise it has all the appearance of being well suited to the manufacture of common brick.

The clay is conveyed from the bank to the factory on cable cars, and passed through a crusher into a Frey-Sheckler brick and tile machine.

The brick are dried in hacks on the yard and burned in scove kilns. Wood is used for fuel, and about three-fourths of a cord is consumed for each thousand brick burned. An examination of the brick which have been burned shows that the clay should be more thoroughly mixed before being moulded into brick. The brick are strongly laminated owing to the imperfect mixing of the clay. Care should be taken to remove the limestone pebbles which are the main cause for the imperfect brick.

HORICON.

Horicon is located near the central part of Dodge County and on the border of an extensive area of marsh land known as the Horicon marshes. One brick yard is operated at this place which is owned by **J. W. Pluck.** The clay which is mined varies considerably in different parts of the bank. The upper portion consists of clay of glacial origin, underneath which occurs a bed of fine calcareous sand and an unknown depth of blue clay.

The clay is soaked in vats and tempered in pug mills operated by horse power. The brick are moulded by hand, dried in hacks on the yard, and burned in scove kilns. It requires twelve days to burn the brick, coal and wood being used for fuel.

This yard was opened in 1896. During the last three years the average annual output has been 500,000. The brick were sold at the yard in 1899 for about $7.00 per M. kiln run.

Laboratory Examination.—Four samples of clay from this yard were examined in the laboratory of the Survey. All were more or less quartzose and slacked very readily, breaking down into somewhat granular masses. Under the microscope the individual grains of one of the samples were found to be mainly over .009 of a mm. in diameter. The medium sized grains were irregular in outline and the larger ones were somewhat rounded. Calcite was observed in this sample.

Another of the samples examined had grains ranging from .014 to .1 mm. in diameter. Many of them were brown or yellow, due to the staining of iron oxide. Rhombic crystals of calcite were quite abundant.

The third sample examined showed individual grains ranging from .0058 to .003 of a mm. in diameter. The smaller grains were .001 mm. or less in diameter, while the largest were .057 mm. The individuals are all unequidimensional and irregular in shape. All three samples indicate a high percentage of quartz and calcite and a low percentage of iron and alumina.

JEFFERSON.

Jefferson is located on the Rock River in the central part of Jefferson County. The deposits of clay are very similar to those which have been developed at Fort Atkinson, Watertown, and other places along this river. Two

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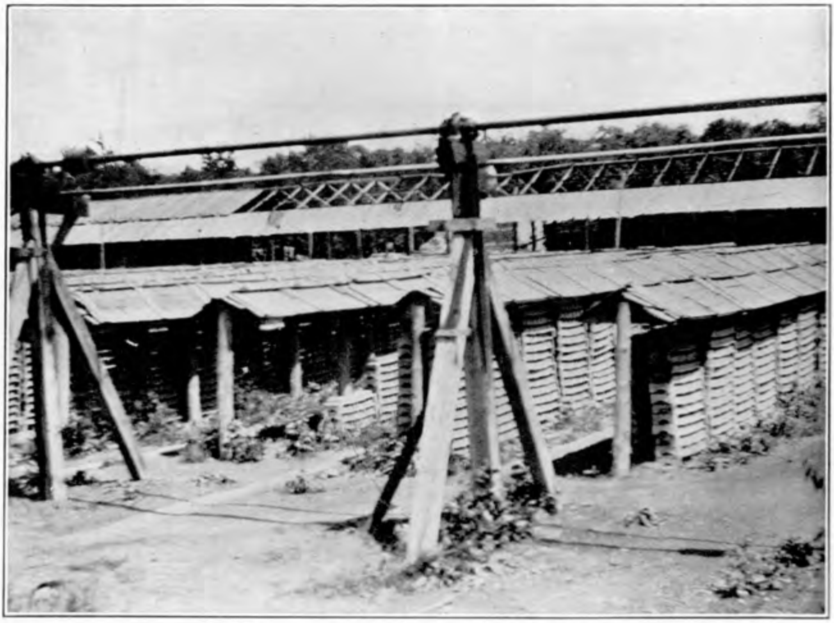

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JEFFERSON BRICK AND TILE COMPANY, JEFFERSON.

FIGURE 1.—CLAY VATS AND CONVEYOR. FIGURE 2.—PALLET SHEDS.

plants known as the Jefferson Brick and Tile Works and Kemmeter Brothers Brick Works are located at this place.

The clay which is now being worked by the Jefferson Brick and Tile Company has a depth of from six to ten feet. In different parts of the bank the percentage of sand, iron oxide, alumina, and calcium are considerably different. One part of the bank consists of what is known as "crab" clay. This name has been given the clay because it has been perforated with crab holes and thereby weathered more completely than other parts of the bank. On account of this weathering the clay is considered superior to that which is taken from other parts of the bank.

The plant of the **Jefferson Brick and Tile Works** is located immediately south of the city, on the Chicago and Northwestern Railroad. It was opened in 1885 and has been operated each year since that time. The company manufactures common brick and drain tile. The clay is hauled in dump carts by team from the bank to the vats where it is soaked over night. Clays from three different parts of the bank are mixed with a small percentage of sand for the manufacture of brick. The clays are soaked in separate vats and mixed as they are shoveled onto the belt conveyer, which carries them to a Potts crusher and from thence to the brick machine. For manufacturing drain tile the most plastic clay in the bank is used with no admixture of sand.

The brick are dried on pallets under sheds and the tile in a building constructed for that purpose. One of the clays from this bank contains such a high percentage of calcium that the brick manufactured therefrom swell after they are burned so that they are larger than when first moulded. The brick and tile have a white or cream color. Those which were examined in the kilns and on the yard were well burned. The tile are burned in round down draft kilns of ordinary construction and the brick are burned in scove kilns.

During the last three years the average annual output of the yard has been from three to three and one-half million brick a year. The brick sold at the yard in 1899 for $5.75 to $6.00 per M. kiln run.

The brick yard owned and operated by **Kemmeter Brothers** is situated on the Hebron road near the city limits. The yard was opened in 1866 and has been worked each year since that time.

The clay bank has been tested and found to have a uniform depth of forty feet, although only the upper ten feet is now worked. The clay contains an occasional pocket of gravel which is removed or worked around in mining. The clay in the upper portion of the bank has a yellowish tint caused by the presence of iron oxide. Below a depth of a few feet the clay is uniformly blue. The clay is mixed with one-third sand and soaked in a vat over night. It is conveyed by means of an elevator from the vat to the soft mud machine in which the brick are moulded. The brick are dried on pallets or in hacks on the yard, and burned in scove kilns. The capacity of the pallet sheds is 175,000 and that of the kilns 1,300,000.

During the last three years the average annual output of the yard has been about 1,200,000. The brick sold in 1899 on board cars for about $6.75 per M. kiln run.

KEWASKUM.

Kewaskum is situated in the northern part of Washington County about eighteen miles west of the lacustrine clay area. The clay which is worked at this place resembles very closely that which occurs at Boltonville near the margin of the lacustrine deposits.

Two brick yards are located near this village. **Charles Mueller and Sons'** yard is situated in the northwest part of the village and **Herman F. Buss'** yard is about one mile and a quarter north of the city.

Mueller's Brick Yard was opened in 1860 and has been operated each year since that time. The average annual output for the last three years has been about 500,000 brick.

Well borings at this place indicate that the clay has a depth of about seventy feet underneath which occurs an unknown depth of sand. The clay is mined to a depth of six feet. It has a bluish color tinted with yellow. The clay is overlain with two to two and a half feet of fine gravelly loam containing an occasional boulder of greenstone or granite.

The clay is plowed and left on the yard for forty-eight hours or more before using. It is then mixed with one-sixth sand and soaked in vats for twenty-four or forty-eight hours. The brick are moulded in a soft mud machine, dried in hacks on the yard, and burned in scove kilns. In 1900 the brick sold for $6.00 to $7.00 per M. kiln run.

The Herman F. Buss Brick Yard is operated by *Albert* and *William Buss.* It is located about one mile and a quarter northeast of Kewaskum. The yard was opened about twenty-four years ago and has been operated from April to October of each year since that time.

At this place the clay has a depth of over forty feet, below which occurs an unknown thickness of gravel. The bank is now mined to a depth of from twelve to fourteen feet. It consists of one foot and a half of gravel, at the surface, one foot of heavy red clay, and twelve feet of yellow clay. The clay underneath the yellow bed is blue.

The clay is plowed, weathered, mixed with one-sixth sand, and then soaked in vats. The brick are moulded in a Wellington soft mud machine, dried in hacks on the yard, and burned in scove kilns. It requires about ten days to burn the brick and one-half of a cord of wood is consumed for each thousand brick burned.

The brick are cream colored and sold at the yard in 1900 for $6.00 per M. kiln run and $7.00 per M. select. The average annual output for the last three years has been 400,000.

The clay which occurs in the vicinity of Kewaskum is very calcareous and consequently unsuitable for the manufacture of either vitrified or refractory wares.

MADISON.

The only brick plant which is located in the vicinity of Madison is owned and operated by **David Stephens.** It is located two miles west of the city on the Chicago, Milwaukee and St. Paul railroad. This is an old and well established yard. Brick have been manufactured here for many years and may be seen in hundreds of buildings in this vicinity.

The bank from which the clay is obtained varies in the thickness of the beds in different parts. The following is the succession of beds at the place where the clay was being worked in 1900:

4 feet of blue clay which burns red,

2–6 feet of coarse yellow sand,

10–16 feet of pink colored clay which burns white,

7 feet of blue clay which burns white.

When the clay from the entire bank is mixed the burned brick have a white or cream color. In case the clay has not been thoroughly mixed the brick will have a streaked red and white color. When underburned the brick have a uniform dull red color.

The clay is transferred from the bank to the factory in dump cars operated by a cable and winding drum. The clay is passed through a Wellington disintegrator to remove an occasional "clay dog" or limestone pebble, mixed in a double pug mill, and moulded in a Monarch soft mud machine.

The brick are dried on pallets under sheds and in hacks on the yard, and burned in scove kilns. The factory has the reputation of manufacturing a good common brick. By setting the brick between the fire holes about twice the distance apart that they are in the upper part of the kiln Mr. Stephens reduces very greatly the quantity of soft brick in the kilns.

The upper four feet of clay is moderately low in calcium and magnesium carbonate, while that below is high in both of these constituents. The clay is suitable for neither vitrified or refractory wares.

The following is a chemical analysis of the surface clay from Madison, similar in composition to that which occurs at the top of Stephens' clay bank:*

Silica	75.80
Alumina	11.07
Peroxide of iron	3.53
Protoxide of iron	0.31
Carbonate of lime	2.45
Carbonate of Magnesia	0.17
Lime (CaO)	0.39
Potash	1.74
Soda	1.40
Water in composition	2.16
Moisture	1.54
Total	99.56

MAYVILLE.

The brick yard at this place is located about one mile east of the city and is owned and operated by **Henry Raabe.** The clay is about sixteen feet in depth, and contains an occasional streak of limestone gravel. The upper part of the clay has a yellowish brown tint, while that below is grayish blue.

The clay is soaked in a vat over night and tempered in wooden pug mills operated by horse power. The brick are made by hand, dried in hacks on the yard, and burned in scove kilns.

The brick are cream colored when properly burned. At present only enough brick are made to supply the local market.

* Geology of Wisconsin, Vol. III, p. 236, analysis made by E. T. Sweet.

MERRIMAC.

Merrimac is located in the eastern part of Sauk County on the north side of the Wisconsin River and on the Chicago and Northwestern railroad. **The Merrimac Brick Company,** of which *Arthur Morey* is the principal owner, operates one of the brick yards at this place.

The clay bank is close to the river and only a few rods from the Chicago and Northwestern railroad. The upper fifteen feet of the bank is a mixture of limestone gravel, granitic boulders, sand, and blue clay. Underneath this, which is mainly stripping, occurs an unknown depth of blue clay. This clay is known to have a depth of fifteen feet which carries it to the level of the water in the river. This clay is laminated and very plastic. It contains an occasional limestone pebble but is much less quartzose than the clay which occurs above. The clay which contains the boulders, as well as the blue clay underneath, is being used at the present time.

The bank is worked with a pick and shovel and the clay is conveyed to the factory in dump cars which are operated by cable and winding drum. The clay is passed through a Wellington disintegrator and the brick are moulded in a new Anderson Chief machine. The brick are dried on pallets under sheds and burned in scove kilns. It requires about ten days to burn the brick and one-half to three-fourths of a cord of wood is consumed for each thousand brick burned. The brick all have a white or cream color when properly burned.

About fifteen men are employed on the yard and the average daily output is 25,000. During four months of 1900 the output of this yard was about 800,000.

The second brick yard being operated near this place is known as **The Brownrigg Brick Yard,** owned by *J. W. Brownrigg.* It is situated two miles from the village of Okee on the south bank of the Wisconsin river, and is directly across the river from the Merrimac Brick Yard.

The clay is transferred from the bank to the mill by means of cars operated by cable and steam hoist. The clay is mixed with one-fourth sand and soaked in a vat. It is then passed through a small pug mill, two crushers, and finally through a second pug mill. From the second pug mill the clay goes directly into an Anderson soft mud machine in which the brick are moulded. The brick are dried on pallets under sheds and burned in scove kilns. About five-eighths to three-fourths of a cord of wood is consumed for each thousand brick burned.

The clay which occurs at this place is ordinarily but incorrectly spoken of as "loess" and has a maximum thickness, according to well borings, of eighty feet. Above the clay occurs from five to twenty feet of sand and reddish brown clay and gravel, all of which is stripped. Underneath this stripping occurs the blue clay which is mined to a depth of from forty to sixty feet. Near the top the clay is interlaminated with beds of sand. The clay has a grayish blue color and contains considerable quantities of very fine sand and calcium carbonate.

MONROE.

Up to the present time two brick yards have been maintained in the vicinity of Monroe. One is owned and operated by **C. B. Churchill** and the other by **Fred Freese.** The clay which occurs at the two yards is essentially the same. It has a depth of about ten feet and is covered with a stripping of from one to one foot and a half of black loam and sod. Underneath the stripping occurs seven feet of yellow sandy clay, which burns red, and three feet of hard blue clay which burns white. When the clay from the entire bank is thoroughly mixed it burns a white or cream color. The clay contains more or less limestone gravel and an occasional flint nodule. Streaks of limonite occur in the clay which would impart a red color to the brick when burned if it were not for the preponderance of lime.

At the yard of **C. B. Churchill** the clay is hauled by cable cars to the vat in which it is soaked. After soaking, the clay is removed on a belt conveyor to a horizontal pug mill from which it is passed into a soft mud machine in which the brick are moulded. The brick are dried on pallets under sheds and burned in up draft kilns having permanent walls.

It requires eight days to burn the red brick and eleven to burn the white. About twenty-three tons of coal and thirteen cords of wood are consumed for each 100,000 brick burned.

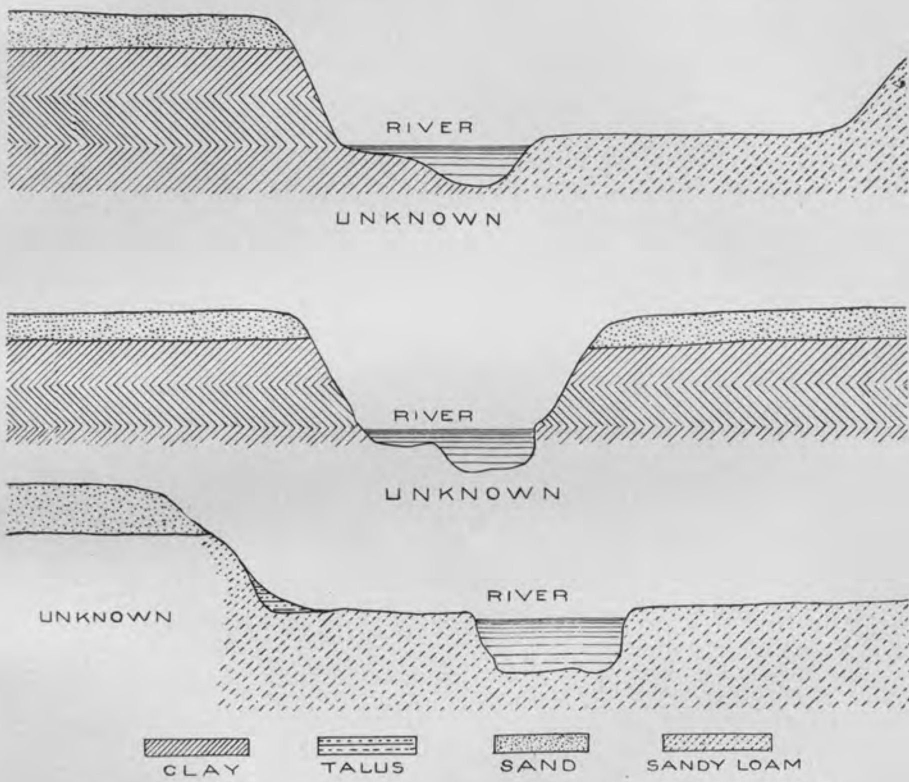
The yard owned by **Fred Freese** is immediately west of Churchill's yard. The clay is soaked in a vat over night and then passed into a Quaker soft mud machine in which the brick are moulded. The brick are dried on pallets under sheds and burned in scove kilns. The average annual output of the yard during the last three years has been about 800,000. The brick were sold in 1899 for $7.00 per M. kiln run.

PORTAGE.

Three brick yards are located at this place and are owned respectively by **Herman Affeldt, A. P. Drinker,*** and **F. L. Sanborn.** The clay which is being used at all of the yards is essentially the same.

Affeldt's Brick Yard is located about half a mile northwest of the Chicago, Milwaukee and St. Paul depot. The clay bank at this place has a thickness of about twelve feet. The upper three feet consists of reddish brown argillaceous sand, underneath which occurs three feet of white sand and from six to eight feet of interstratified clay and sand. The clay has a yellowish gray color and is very similar to that which occurs at Merrimac. The clay is soaked in a vat and tempered in wooden pug mills operated by horse power. The brick are moulded by hand, dried in hacks on the yard and burned in scove kilns. The brick are cream colored.

* This yard was abandoned in 1900 and the machinery sold to F. L. Sanborn.



TYPICAL SECTIONS ACROSS THE WOLF RIVER CHANNEL ABOVE SHIOCTON.

This yard was opened about twenty-two years ago and has been operated each year since that time. The average annual output during the last three years has been about 500,000. The brick sold in 1899 for about $6.00 per M. kiln run.

The brick yard owned and operated by the **Sanborn Brick and Ice Company** was opened in 1874 and has been operated each year since that time. The clay bank which is being worked has a thickness of twenty feet and consists of interstratified sand and clay similar to that which occurs at Affeldt's yard. The clay is soaked in vats and tempered in pug mills operated by steam power. The brick are moulded by hand,* dried in hacks on the yard, and burned in scove kilns. Building and sidewalk brick are manufactured.

During the last three years the average annual output of this yard has been about 800,000.

Drinker's Brick Yard is located in the western part of the city. The clay bank consists of about two feet of yellowish brown clay at the top, underneath which occurs one foot to one foot and a half of fine sand and twenty feet of grayish colored clay which is worked to a depth of four or five feet.

The clay is conveyed from the bank to the works by means of cable cars and is tempered in a pug mill. The brick are made in a Creager and Son's soft mud machine, dried on pallets under sheds, and burned in scove kilns. The clay burns to a cream color but the sand used in moulding gives the brick a grayish tint.

Laboratory Examination.—Both the clay and moulding sand used at this yard were examined in the laboratory of the Survey. The top or yellow clay slacks very readily breaking down into a finely pulverulent mass. It is free

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* Since writing this report Mr. Sanborn has purchased the machinery formerly used by A. P. Drinker, and the brick are now made in a Jonathan Creager & Son's soft mud machine.

from coarse particles and very plastic. The microscopic examination shows that it is composed of grains which have an average diameter of about .0058 mm. The largest grains do not exceed .011 mm. in diameter while the smaller ones are less than .001 mm. in diameter. The individual grains have an irregular and occasionally roundish outline. Besides the iron oxide which stains the mass of the clay, calcite and quartz are the principal recognizable constituents.

The sample of blue clay slacked somewhat slower than the yellow, breaking down into fine flakes. In its smooth, plastic character it is very similar to the preceding sample. Under the microscope it was found to consist mainly of grains which correspond in size with those of the clay above described. A few grains of sand were observed which measured .25 to .20 mm. in diameter.

One of the samples of moulding sand submitted for inspection was composed of grains not over .33 mm. in diameter and having an average size of about .1 mm. The individual grains were mainly quartz, although a considerable quantity of calcite and feldspar were noticeable.

The second sample of moulding sand examined was somewhat finer than the first. A large part of the sand was made up of grains having an average diameter of .083 mm. although a majority of the grains were less than .005 mm. in diameter. Many of the individuals are angular in outline, showing clean, sharp, fractures. Calcite and feldspar, as well as quartz, are abundant constituents. The grains are discolored with iron oxide giving them a slightly yellowish brown tint. This clay is unsuitable for the manufacture of either vitrified or refractory wares.

SCHLEISINGERVILLE.

Schleisingerville is located near the center of Washington county, about twenty miles west of the limit of the lacustrine clay deposits. The bank which is being worked consists of four feet of loam, which is stripped, underneath which occurs from three to five feet of yellowish colored clay, which burns red, and from fifteen to twenty feet of blue clay all of which burns white. An occasional pocket of limestone gravel occurs in the clay necessitating care in working the bank.

Two brick yards are located at this place, one of which is owned and operated by **L. Rosenheimer** and the other by **P. W. Kortmeyer.** Both yards are located a short distance east of the village and are on opposite sides of the Wisconsin Central railroad.

The clay bank connected with the Kortmeyer yard has been worked out and clay is now obtained from the Rosenheimer yard.

The clay is most easily worked when it has been weathered over winter. It is mixed with about one-fourth sand and soaked in vats over night. The brick are moulded in an "Old Reliable" soft mud machine, dried in hacks on the yard, and burned in scove kilns.

This yard was opened in 1884 and has been operated each year since that time. During the last three years the average annual output has been 400,000. The brick sold on the market in 1899 for $4.50 per M.

At Rosenheimer's yard the clay is worked in about the same manner as at Kortmeyer's. The brick are moulded in a soft mud machine, dried in hacks on the yard, and burned in scove kilns. This yard is equipped with a combination brick and tile machine and a crusher, neither of which have been used for several years. It requires from eight to nine days to burn the brick and about one half cord of wood is consumed for each thousand brick burned. During the last three years the average annual output of the yard has been about one million brick. The brick were sold at the yard in 1899 for about $5.50 per M. kiln run.

SPRINGFIELD.

Springfield is located near the central part of Walworth county and about eight miles from Elkhorn. **The Springfield Brick and Tile Company** of which *R. Trist* is owner is located about one-half mile south of the village. The clay which occurs at this place has a thickness of from two to ten feet above which is a stripping of from six to eight inches of sod. The clay contains very little limestone gravel and the brick and tile which were examined on the yard show no evidence of its occurrence. The distribution of the clay is irregular and in places it is overlain with deposits of limestone gravel.

After removing the clay from the bank it is soaked in vats over night and then passed through a Potts disintegrator. The brick and tile are made in a Little Wonder brick and tile machine, dried in a three story building constructed for the purpose, and burned in round down draft kilns of latest pattern.

This yard was opened in 1896 and has been operated each year since. The annual output of brick has been in the neighborhood of 100,000. The brick sold in 1899 at prices ranging from $7.00 to $9.00 per M. kiln run.

The clay which occurs at this place burns a beautiful cherry red and the brick and tile manufactured therefrom are of excellent quality. From all appearances this is one of the best clays in southern Wisconsin for the manufacture of red flower pots, drain tile, and brick. The clay might also be used in the manufacture of terra cotta. For a number of years the clay from this locality has been used by the Edgerton Art Pottery Works for the manufacture of ornamental pottery.

Laboratory Examination.—The microscopic examination of samples of this clay shows that it consists of grains which are moderately coarse. One of the samples was composed of grains which averaged about .02 mm. in diameter. The largest grains observed in this sample were .125 mm.

in diameter while there were myriads less than .01 mm. in diameter.

The other sample examined consisted of individuals averaging about .014 mm. in diameter. The largest grains observed were .1 mm. in diameter, while a small percentage of the grains were under .003 mm. in diameter.

Between the largest and smallest grains in both samples there are all gradations. The individuals are mainly subangular in outline, although the larger grains are usually somewhat rounded. The grains are stained brown or yellowish brown with iron oxide.

Quartz appears to be the main constituent. A few grains of calcite were observed but the proportionate amount is thought to be low. The kaolin occurs among the finer grained constituents and comprises a moderately small percentage of the clay.

The chemical composition of the clay is shown by the analysis in table I of the Appendix.

WATERTOWN.

Watertown is situated near the northern boundary of Jefferson county on the Chicago, Milwaukee & St. Paul railroad. Two brick yards are located at this place, one of which is owned by **L. H. Cordes and Company** and the other by **Cordes, Vaughn and Company.** Both are now being operated under the management of *L. H. Cordes and Company.* The combined output of the two yards is in the neighborhood of five million brick per year. The stock is graded and sold as common, chimney, sidewalk, well, and veneering brick.

The clay at this place has a total thickness of about twenty-five feet. The upper four or five feet contains a considerable percentage of sand and has a yellow color. The remaining twenty feet has a blue color and contains much less sand. The bank is now worked to a depth of about ten or twelve feet and the yellow and blue clays are mixed together in equal proportions. To the clay as it comes from the bank about one-fifth sand is added. The clay is run through a crusher and then soaked for twenty-four hours in vats. The brick are moulded in soft mud machines, operated by steam power, dried in hacks on the yard, and burned in scove kilns. The clay from this bank is very free from gravel and was at one time used in the manufacture of pottery.

The clay which occurs at the yard owned by **Cordes, Vaughn and Company** is essentially the same as that at the yard just described. The clay is mined with a pick and shovel and soaked in a vat over night. The brick are made in a soft mud machine, dried in hacks on the yard, and burned in scove kilns. The brick manufactured at both yards have a white or cream color.

Laboratory Examination.—The clay from the first named yard was examined in the laboratory of the Survey. It is somewhat hard and brittle when dry but slacks very readily in water, breaking down into a scaly mass which is very smooth and plastic.

The microscopic examination shows that the clay consists of individuals which have an average diameter of .003 mm. Many of the grains, however, are .014 mm. in diameter, and the largest have diameters of .04 mm. Quartz and calcite are both present in the clay but in undeterminable proportions. As a rule the individuals have sub-angular outlines and are unequi-dimensional in size.

The chemical composition of the clay is given among the analyses recorded in table I of the Appendix.

The brick which are manufactured from this clay have a white or cream color and are among the more desirable products of the calcareous clay region. Besides building brick, the clay is undoubtedly suitable for the manufacture of some of the commoner kinds of earthenware such as flower pots.

WIND LAKE.

The Wind Lake Brick and Tile Company is located at Wind Lake in the north central part of Racine county.

The clay at this place resembles very closely the lacustrine clays which have been described in the previous chapter.

The clay bank consists of a stripping of from one foot to one foot and a half underneath which occurs an unknown thickness of clay which is worked to a depth of eight or ten feet. Limestone gravel is abundant in some portions of the bank but the clay which is now being used contains only an occasional pebble. The upper two feet of the clay burns red and the remainder white.

The clay is soaked for twenty-four hours and then passed through a crusher into a stiff mud brick and tile machine, provided with an automatic end cut-off. The brick and tile are dried in sheds, by air, and burned in square down draft kilns.

Laboratory Examination.—The clay from this yard was examined in the laboratory of the Survey. It was found to be moderately hard when dry and very plastic when wet. It slacks readily breaking down into thin flakes.

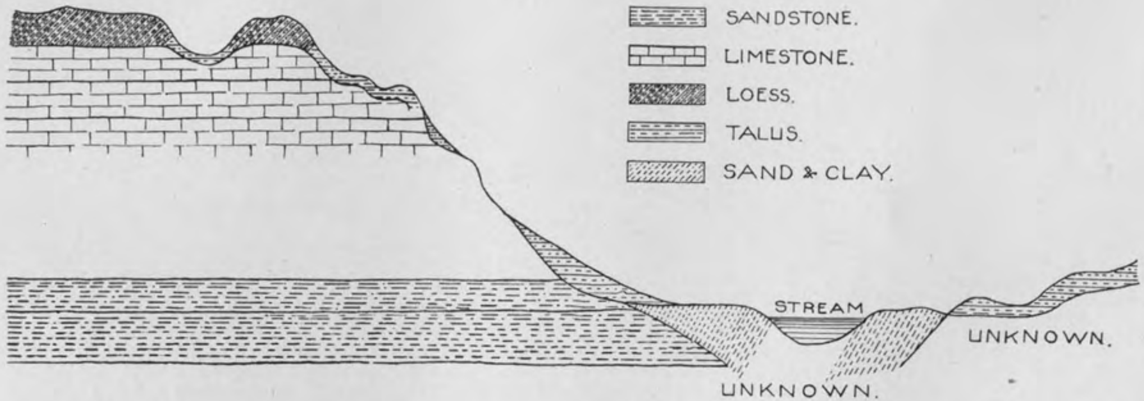
The microscopic examination shows the clay to consist of grains having an average diameter of about .03 mm. With the exception of rhombic individuals supposed to be calcite or dolomite, the individuals are mainly well rounded or sub-angular in outline.

CHAPTER IX.

CLAYS OF THE DRIFTLESS AREA.

The Driftless Area comprises that portion of the state which has not been modified by the ice sheets of the glacial period. It comprises the southeastern portion of the state as outlined on the general map, plate I. None of the rivers of this region with the exception of a small part of the Wisconsin drain that portion of the state comprising the two areas previously described. The northern and northeastern parts of the area have been slightly modified with overwash from the glaciers but other than this it is a region of typical erosion topography in which the surface deposits are either the result of rock disintegration in situ or deposition from streams and air. The underlying rocks consist of sandstone and limestone. The northern part of the area, including Adams, Juneau, Monroe, Jackson, La Crosse, Trempealeau and Buffalo counties, is largely underlain with Potsdam sandstone. The southern two-thirds of the area is mainly underlain with limestone. The clay deposits of this region are largely residual having been formed through the decomposition of the underlying limestone and sandstone.

In the transported deposits large quantities of quartz which has been derived from the decomposition of the associated sandstone is frequently mingled with the clay resulting from the decomposition of the limestone. Through the decomposition of the limestone most of the calcium and magnesium salts are taken into solution and removed by percolating waters, *leaving a residuum of quartz, iron oxide, and kaolin.*



TYPICAL SECTION OF A RIVER VALLEY AND ADJACENT HILL IN THE DRIFTLESS AREA; SHOWING THE POSITION OF THE CLAY DEPOSITS.

The clay deposits in this region are mainly a result of the *decomposition* of the country rock, while the clay in the two regions previously discussed has resulted very largely from *disintegration* of the underlying rock.

It is thought by T. C. Chamberlin, R. D. Salisbury, and others that the clay occuring on the tops of the high bluffs and ridges extending for some distance east of the Mississippi river has been carried to its present position by winds. For this reason these clay deposits are known to geologists as "Loess." These deposits of loess are very similar to the brown or reddish brown clay which has been classed in many places over the driftless area as residual. In fact so close is the similarity between the brown residual clays and the loess that it is difficult to map them as distinct and separate deposits.

The approximate extent of the loess deposits is shown on the map, plate I. (After Chamberlin.) I do not feel sure that the loess and residual clay deposits can be clearly differentiated from each other in this region and therefore no attempt is made to separate them in the following discussion.

The limestones of the Driftless Area are both quartzose and ferruginous and it would be natural to anticipate that the clays resulting from their decomposition would contain considerable quantities of quartz and iron oxide. An examination of the clays from many parts of this region verifies the above presumption. Further, it is found that the residual clays of this region which have been worked over and re-deposited by the rivers usually contain greater quantities of quartz than those that have been undisturbed.

The clays of this region are both residual and transported. The residual clays are the unmodified deposits resulting from the decomposition of limestone. They occur mainly on or near the tops of the ridges, hills, and tablelands which are or have been capped with limestone and frequently contain fragments of flint or chert. The transported clays are residual deposits which have been moved a greater or less distance and assorted and re-deposited either by water or wind. The residual and loess deposits and their equivalents which have been transported only a short distance are the richest clays of the area. The transported clays have as a rule been carried through a region partially composed of soft incoherent sandstone, which has contributed large quantities of fine quartz sand to the rivers. This sand now occurs mingled with the residual limestone material which has been transported from higher altitudes. Moreover, in the lower courses of the streams the tributaries often supply no other material than sand, so that the clay may constitute a very small percentage of the alluvial deposit. For this reason the deposits which are now accumulating in the quiet stretches of the river channels and those which have been formed in the past, often contain scarcely sufficient clay to hold the particles together when moulded.

All the clay of this region contains considerable quantities of iron oxide and is low in calcium. Accordingly the brick and tile which are manufactured are different shades of red depending upon the amount and condition in which the iron oxide is present. The deposits are everywhere comparatively thin and the continuous areal extent varies greatly. Residual deposits of clay occur adjacent to most of the cities throughout a greater part of this area. The clay is comparatively easy to work and when not too sandy makes a good common building brick. Brick yards are quite numerous in this region but owing to the situation and character of the clay the factories are small and the methods of manufacture somewhat primitive. The brick are manufactured mainly to supply local demands.

The following is a brief description of the more important brick yards which are now operated in this region. There are undoubtedly a number of factories located some distance from any railroad which have been unintentionally omitted.

ARCADIA.

Arcadia is situated in the western part of Trempealeau county on the Green Bay & Western railroad. Two brick yards are located at this place, one of which is owned and operated by **Ernest Pahl** and the other by **Zimmermann and Company.** The clay which occurs at both yards is of alluvial origin and consequently laminated.

The yard owned and operated by **Ernest Pahl** was opened in 1891 and has been operated each year since that time. The average annual output of the yard for the last three years has been in the neighborhood of 250,000. The clay bank consists of a stripping of about one foot and a half of black loam, underneath which occurs four feet of yellow and two feet of blue clay, both of which burn red. The blue clay is not used in the manufacture of brick. About one-tenth of the black loam is mixed with the yellow clay to serve the purpose of sand. The brick are made by hand, dried in hacks on the yard and burned in scove kilns. It requires a little over one-fourth of a cord of wood to burn each thousand brick.

The brick yard owned by **Zimmermann and Company** is located north of the plant owned by **Ernest Pahl.** It was opened in 1898 and has been operated each year since that time. The clay is essentially the same as that which is mined at Pahl's yard. The average annual output of the yard is from 250,000 to 500,000. The brick are moulded in a Quaker soft mud machine operated by horse power, dried on pallets under sheds, and burned in scove kilns.

The brick at both factories are not burned very hard owing to the sandy character of the clay and the difficulty experienced in controlling the heat. The brick were sold in 1899 at an average of $5.00 per M. kiln run.

BANGOR.

Bangor is located in the western part of La Crosse county on the Chicago, Milwaukee and St. Paul railroad.

One small yard owned by **Max Stegman** is located about four miles south of the village in what is known as Dutch Valley. The clay at this place has a reddish brown color and occurs near the bottom of the hills where the yard is located. The clay is mainly a residual limestone deposit which has been washed from above. The clay is mixed in a wooden pug mill operated by horse power. The brick are moulded by hand, dried in hacks on the yard, and burned in scove kilns.

The brick have a bright red color and are a good average of the red brick manufactured from similar clay in this region.

BLOOMINGTON.

Bloomington is situated in the northwestern part of Grant county and about ten miles from Lancaster. The **Bloomington Brick Yard** which is located at this place is owned and operated by *Mr. Hutton.* The yard was opened in 1897 and has been worked each year since that time. Common red brick are manufactured.

The clay bank has a working depth of five feet. The clay is fairly rich at the top but very sandy near the bottom. The clay is soaked in vats over night and tempered in wooden pug mills operated by horse power. The brick are moulded by hand, dried in hacks on the yard, and burned in scove kilns. It requires seven days to burn the brick and about one-third of a cord of wood is consumed in burning each thousand brick.

The average annual output of the yard has been about 350,000. The brick sold at the yard in 1899 for about $7.00 per M. kiln run.

Between Bloomington and Cassville various thicknesses of clay similar to the above are found on the tops and near the bottom of the ridges, and at the heads of the valleys.

CASSVILLE.

Cassville is situated in the western part of Grant county on the Chicago, Burlington, and Northern railroad. The brick yard which is located at this place is owned and operated by **James Barrows and Son.** The yard is situated in the north end of the city. The clay has a yellowish brown color and has apparently been washed into the valley from the adjacent hills. The clay is very sandy, and the brick examined were not very strong.

The clay is soaked in a vat over night and tempered in a wooden pug mill operated by horse power. The brick are moulded by hand, dried in hacks on the yard, and burned in scove kilns.

ELROY.

Elroy is located in the western part of Juneau county on the Chicago & Northwestern railroad. The only brick yard at this place is owned and operated by **Loveland (E. N.) and Wade (J.).** The plant is located on the Chicago & Northwestern railroad about one-half mile east of the city. The clay bank which is being worked has a thickness of about two and a half feet. The clay has a yellowish brown color and burns red. In the valley of the Lemonweir river, adjacent to which the yard is located, occurs a large quantity of blue clay which, however, contains a large percentage of sand and is thought to be less suitable for the manufacture of brick than that which is now being used.

The clay is soaked over night in a vat and tempered in a wooden pug mill operated by horse power. The brick are moulded by hand, dried on pallets under sheds, and burned in scove kilns. The company owns a stiff mud machine which is not being used at the present time.

During 1900 the company manufactured in the neighborhood of 250,000 brick.

GALESVILLE.

Galesville is situated in the southern part of Trempealeau county on the Chicago & Northwestern railroad. One brick yard, owned and operated by **B. T. Dale,** is located about two miles west of the city. The bank from which the clay is obtained is situated at the base of one of the low ridges and has a thickness of from twelve to fourteen feet. The top of the bank is richest and has a deep yellowish brown color. Toward the bottom of the bank the clay has a light yellowish tint and is very fine grained and quartzose. The clay has a laminated structure which gives it very much the appearance of being of sedimentary origin. The lamination, however, is probably due to other causes than sedimentation.

This yard was opened in 1893 and about 500,000 brick are manufactured annually all of which are sold in the vicinity of Galesville.

The clay is soaked over night in a vat and conveyed to an Eagle soft mud machine, operated by horse power, in which the brick are moulded. The brick are dried on pallets under sheds and in hacks on the yard and burned in permanent up draft kilns. It requires about twelve days to burn the brick. The brick are various shades of red and do not differ materially from other brick manufactured in this area.

HILLSBORO.

Hillsboro is located in the eastern part of Vernon county about seven miles west of Wonewoc. The plant which is located at this place is owned and operated by **Joseph Bezucha.** The clay which is mined has a deep reddish brown color and is very similar to that which occurs in many places throughout this region. The clay has a depth of from six to ten feet and is very sandy. It is mixed in wooden pug mills operated by horse power. The brick are moulded by hand, dried in hacks on the yard, and burned in scove kilns.*

Kiln run brick were sold in 1899 for $6.00 per M. and chimney brick for $8.00. The brick are only manufactured to supply the local demand.

INDEPENDENCE.

Independence is located in the northwestern part of Trempealeau county near the northern limit of the magnesian limestone region. The only brick yard operated at this place is owned by **Henry Hartzfeldt.** The clay occurs near the base of one of the numerous ridges of this region. It has a thickness of about four feet and has a deep yellow or yellowish brown color. The clay at the bottom of the bank is mainly sand.

The clay is soaked in a vat and mixed in wooden pug mills operated by horse power. The brick are moulded by hand, dried in hacks on the yard and on pallets under sheds, and burned in scove kilns.

This yard was opened in 1895 and has been operated each year since that time. The brick have the usual red color to which the clay of this area burns. The brick sold in 1899 for $7.00 to $8.00 per M. kiln run at the yard. The market is local.

LA CROSSE.

La Crosse is situated in the western part of the state near the junction of the La Crosse and Mississippi rivers. Four brick yards are located near the outskirts of the city and are owned respectively by Anton Keppel, Hermann Keppel, Mike Meyer, and Schnell Brothers.

The yard owned by **Anton Keppel** is located three miles east of La Crosse. The clay is obtained from the side of small knolls or near the base of the bluffs which skirt the

* Since writing this report this yard has been equipped with modern machinery.

river at this place. The bank which is now being worked has a thickness of from three to six feet. The clay has a yellowish brown color and contains very much fine sand.

After the clay is removed from the bank it is soaked over night in a vat and mixed with a tempering wheel. The brick are made by hand, dried in hacks on the yard, and burned in scove kilns. This yard was opened twenty-six years ago and has been operated each year since that time. The average annual output has been from 100,000 to 300,000. The brick sold in 1899 for about $5.00 per M. kiln run.

The brick yard owned and operated by **Herman Keppel** is about one-fourth of a mile north of Anton Keppel's yard. The clay bank is situated at the foot of the bluffs bordering the river and has a thickness of about seven feet. The clay in the lower portion of the bank is very sandy. It is soaked in a vat over night and mixed with a tempering wheel operated by horse power. The brick are moulded by hand, dried in hacks on the yard, and burned in scove kilns. It requires about seven days to burn the brick and about one-fourth of a cord of wood is consumed for each thousand brick burned.

This yard was opened thirty-three years ago and has been operated each year since that time. The average annual output of the yard has been about one million brick. The market price in 1899 was about $5.25 per M. kiln run at the yard.

The yard owned and operated by **Mike Meyer** is located about two miles east of the city. This yard was opened in 1883, and has been operated each year since that time.

The clay occurs in a small valley between the bluffs which skirt the river. The clay bank has a depth of about eight feet, one to two feet of which is sand and six feet clay. The clay has a reddish brown color and is moderately tough and plastic.

The clay is soaked over night in a vat and mixed with a tempering wheel. The brick are moulded by hand, dried in hacks on the yard, and burned in scove kilns.

During the last three years the average annual output of this yard has been about 175,000. Common brick sold at the yard in 1899 for about $5.00 per M. kiln run.

The yard owned and operated by **Schnell Brothers**, which is located about four miles east of La Crosse, was opened in 1890 and has been operated each year since that time. The clay bank occurs near the base of a low bluff and has a depth of about twelve feet. The upper four or five feet is a tough yellowish brown clay, underneath which occurs from six to seven feet of yellow sandy clay.

The clay is soaked in vats and mixed with a tempering wheel. The brick are moulded by hand, dried in hacks on the yard, and burned in scove kilns. It requires from seven to eight days to burn the brick and about one-fourth of a cord of wood is consumed for each thousand brick burned.

During the last three years the average annual output has been in the neighborhood of 1,200,000 brick. The brick sold in 1899 for about $5.00 per M. kiln run.

LE FARGE.

Le Farge is a small village in Vernon county, situated at the northern terminus of the Kickapoo & Northern railway. The only brick yard located at this place is owned and operated by **V. V. Miller.** The clay bank occurs near the base of the bluffs which border the Kickapoo valley. The clay has a yellowish brown color and has a depth of about two and a half feet. The brick are moulded by hand, dried in hacks on the yard, and burned in scove kilns. It requires about seven days to burn the brick and one-fourth of a cord of wood is consumed for each thousand brick burned. The output in 1899 was about 200,000 brick. They sold at the yard in 1899 for $6.00 per M. kiln run.

LANCASTER.

Lancaster is located near the center of Grant county. The only brick yard at this place is owned and operated by **William Barrows.** The clay occurs near the top of the table land area on which the city is situated. Well borings in this vicinity indicate that the clay has a maximum depth of forty feet which is far above the average for this region. The clay is now worked to a depth of three feet. It has a yellowish brown color with an occasional blue spot. The three feet of clay immediately underneath is hard and tough and is seldom used owing to a tendency which the brick made therefrom have of cracking during the process of drying. Underneath this layer of tough clay there is reported to be ten feet of smooth putty-like blue clay. In most places in this vicinity, however, there is no clay below the yellow bed which itself does not exceed three to six feet in thickness.

The clay is tempered in a pug mill operated by horse power. The brick are moulded in a hand press, dried in hacks on the yard, and burned in scove kilns. The average annual output of the yard is about 200,000 brick. In 1899 the brick sold at the yard for about $6.00 per M. kiln run.

MAUSTON.

Mauston is located in the southeastern part of Juneau county on the Chicago, Milwaukee & St. Paul railroad. The clay which is being worked at this place differs somewhat from that which occurs in most parts of this area. The deposit is in the valley of the Lemonweir river and is of alluvial origin. The exposed clay bank consists of a foot of black loam or sod which is stripped, two and one-half to three feet of bluish, sandy clay, and an unknown thickness of laminated red clay which is now worked to a depth of four or five feet.

The brick yard located at this place is operated by the **Dayton Brick Company** and is owned by *James Dayton.* The yard was opened in 1890 and has been operated each year since that time with the exception of 1896. The clay is soaked for several days in a vat and from thence conveyed directly to a Penfield stiff mud machine in which the brick are moulded. The brick are dried on pallets under sheds and in hacks on the yard and burned in scove kilns.

The average annual output of this yard is about 100,000. The average price of the brick in 1899 was about $7.00 per M. kiln run.

PLATTEVILLE.

Platteville is located in the eastern part of Grant county on the Chicago & Northwestern and Chicago, Milwaukee & St. Paul railroads. The only brick yard located at this place is owned and operated by **John Grindell.** The bank from which the clay is obtained has a thickness of from five to ten feet. Below the sod at the surface occurs a thickness of two and a half feet of workable clay, from three to eight feet of clay known as hard pan, and an undetermined depth of gravel. The clay at the surface has a dark yellowish brown color and is very plastic. It is mixed and tempered in pug mills. The brick are made in a Monarch soft mud machine, dried on pallets under sheds, and burned in scove kilns. This is the only brick plant in the state where the power is furnished by a gasoline engine.

Laboratory Examination. The clay which occurs near the surface has a somewhat lighter color than that which occurs deeper within the bank. Both samples examined slacked quickly in water breaking down into fine scaly masses which were very plastic. The plasticity of the lower clay appears to be somewhat greater than that of the clay which occurs near the surface.

Under the microscope it was observed that the largest grains are not over .1 mm. in diameter. The surface clay consists mainly of grains ranging from .014 mm. to .003

mm. in diameter. The lower clay consists of grains that are mainly under .003 mm. in diameter.

Many of the larger grains are fairly well rounded, but the smaller individuals are irregular and angular in shape. Quartz, iron oxide, and an occasional calcite grain could be detected.

The chemical composition of both the upper and lower clays will be found in the table of chemical analyses.

REEDSBURG.

Reedsburg is located in the northwestern part of Sauk County on the Chicago and Northwestern Railroad.

There are three brick yards operated in the neighborhood of this city, which are owned respectively by Fred Bergmann, Henry Fuhlbohm, and Lewis Halbersleben.

The yard of **Fred Bergmann** is located about one mile southwest of the city. The bank from which the clay is obtained has a thickness of from four to five feet. The clay has a yellowish brown color and burns red. The brick are moulded by hand, dried in hacks on the yard, and burned in scove kilns.

The brick yard owned by **Henry Fuhlbohm** is east of Bergmann's yard and has been idle for two years. The clay is the same as that occurring at Bergmann's yard and the brick are manufactured in the same manner.

The yard owned and operated by **Lewis Halbersleben** is about one mile west of the city. The bank from which the clay is obtained has a thickness of about five feet. The clay is soaked in a vat for two days and then mixed in a wooden pug mill operated by horse power. The brick are moulded by hand, dried in hacks on the yard, and burned in scove kilns. All of the brick manufactured in this vicinity are red.

RICHLAND CENTER.

One brick yard is located at this place which is owned and operated by **Lewis Minisini.** The clay is of residual origin modified by running water. It is quite sandy and burns a red color. The brick are made by hand and burned in up draft kilns.

SPARTA.

Sparta is located in the western part of Monroe County on the Chicago, Milwaukee and St. Paul. Railroad. The **Sparta Brick Works** are owned and operated by *P. S. Sparling*. The clay bank occurs near the base of one of the bluffs in this vicinity and consists of one foot of black loam at the surface, from eight to nine feet of yellowish brown clay, and an undetermined thickness of sand. The quantity of sand in the clay increases as the bottom of the bank is approached. The clay is soaked in a vat over night. The brick are manufactured in a Quaker soft mud machine, dried in hacks on the yard, and burned in scove kilns. The brick are burned eight days and it requires about one-fifth of a cord of wood for each thousand brick burned. The brick have a red color.

This yard was opened in 1877. The average annual output is about 400,000. In 1899 the brick sold at an average of $6.00 per M. kiln run.

SPRING GREEN.

Spring Green is located in the southwestern part of Sauk County on the Chicago, Milwaukee and St. Paul Railroad. The only brick yard located at this place is owned and operated by **G. F. Post.** It was opened in 1898 and has been operated each year since that time. The clay which occurs at this place has a blue color and is streaked with red and yellow.

After removing the clay from the bank it is soaked in a vat. The brick are moulded by hand, dried in hacks on the yard, and burned in scove kilns. The output of this yard in 1898 was 250,000. The brick sold at the yard in 1899 at an average of $6.00 per M. kiln run.

SOLDIERS GROVE.

Soldiers Grove is located in the southeastern part of Vernon County on the Kickapoo and Northern Railroad.

The brick yard operated at this place is owned by **Atley Peterson.** The yard is located on the west bank of the Kickapoo River, one-fourth of a mile north of the city. The clay which occurs at this place is about two and a half feet deep and has a reddish brown color.

The clay is mixed in a wooden pug mill operated by horse power. The brick are moulded by hand, dried in hacks on the yard and burned in scove kilns. It requires about seven days to burn the brick.

VIROQUA.

Viroqua is located on the Chicago, Milwaukee, and St. Paul Railroad in the central part of Vernon County. The only brick yard in this vicinity is owned and operated by **Silas Foster.** The bank from which the clay is obtained is near the base of one of the numerous hills in this region. The clay has a total depth of about three feet. It is mixed with about one-eighth of its bulk of coarse sand, and soaked in a vat over night. The brick are moulded in a Quaker soft mud machine, dried in hacks on the yard and on pallets under sheds, and burned in scove kilns. It requires nine days to burn the brick and two-fifths of a cord of wood is consumed for each thousand brick burned.

This yard is supplied with an excellent red sand for moulding on account of which the brick have a cheerful red color. This ferruginous sand is also used for coloring mortar and as such answers the purpose of the red pigment which is ordinarily used for this purpose.

Laboratory Examination.—The samples of clay examined from this yard slacked readily in water breaking down into loose fluccolent masses.

The samples differ mainly in the size of the grains and the quantity of quartz present. The individuals are mostly stained a dirty brown with the iron oxide which occurs in considerable quantities. The individuals vary in size from those having diameters of .1 of a mm. to those in which the greatest diameter is less than .001 mm. The large grains are fairly well rounded, while the small individuals are somewhat angular.

The only minerals which could be identified with certainty were quartz and iron oxide. The chemical composition of the clay is given in table I of the Appendix, to which the reader is referred.

WONEWOC.

Wonewoc is located on the Chicago and Northwestern Railroad in the southern part of Juneau County. The brick yard located at this place is owned and operated by **Benjamin Truber.** The clay is an alluvial deposit occurring in the valley of the Lemonweir River. The bank consists of a stripping of soil of from ten to eighteen inches and three feet of clay.

The clay has a bluish color mottled with streaks of yellowish brown iron oxide. The clay is soaked in a vat over night and then passed directly into a Quaker soft mud machine in which the brick are moulded. The brick are dried mainly on pallets under sheds and burned in scove kilns.

This yard is equipped with a dry press machine and permanent up draft kilns. The dry press machine has not yet been used and the suitability of the clay for this kind of brick has not been demonstrated.

Mr. Truber first began making brick by hand and alone. Later he installed a foot press and finally purchased a soft mud machine operated by steam power. The brick were first dried in hacks on the yard but later pallets and sheds were constructed, upon which the brick are now being dried.

Laboratory Examination.—Two samples of clay from this yard were examined in the Survey laboratory. The surface clay differs from that underneath simply in containing less sand and having grains of more uniform size. The clay from both parts of the bank slacks quickly in water, breaking down into a granular mass which is very plastic. The microscopic examination shows that the grains are from .057 mm. to .0014 mm. in diameter. They are roundish to subangular in outline. The large grains are mainly quartz. A small amount of chlorite occurs throughout the clay and iron oxide is present as an abund-nant staining agent. The chemical composition of the clay is given in table I of the Appendix, to which the reader is referred.

CHAPTER X.

GLACIAL CLAYS FROM THE REGION NOT UNDERLAIN WITH LIMESTONE AND OUTSIDE OF THE AREA OF LACUSTRINE CLAYS.

The clays of this class have a greater areal extent than any of those previously described. The region throughout which they occur comprises a large part of the northern half of the state, all of which is underlain either with the pre-Cambrian crystalline rocks or Potsdam sandstone. These clays have been derived mainly from the igneous rocks and their mineralogical composition resembles somewhat the residual deposits which might result from the decomposition of such rocks. The glacial deposits in the northeastern part of the state contain some limestone gravel derived from the finely crystalline marble and limestone occurring to the northeast. The glacial abrasion of this section was not on the whole as intense as it was in the southeastern part of the state in the region traversed by the Green Bay glacier, owing partially to the harder and more resistent character of the country rock. This naturally resulted in decreasing the quantity of silt furnished to the rivers by the melting glaciers.

In some parts of this region, as in the southeastern part of the state, the river channels were at times during the glacial epoch nearly, if not quite, filled with almost stagnant water in which was deposited . considerable thickness of clay. These deposits, however, have since that period been largely removed. Only occasionally is there a part of this deposit found in some sheltered part of the present river channels. In some places the clay has been re-deposited along the present stream channels and on the bottom of the lakes, forming the most recent clay deposits. Much of the clay, however, occurs as it was deposited from the glacial ice, mingled with gravel and boulders.

The deposits have a very uncertain and variable thickness. The composition may be very different in two deposits which are almost contiguous. The clays occurring in this region are among the best and poorest in the state. The most valuable deposits are those which are supposed to have been formed prior to and contemporaneous with the last glacial epoch. These deposits sometimes attain a thickness of forty or fifty feet and are remarkably uniform over considerable areas.

The clays that are supposed to be pre-glacial consist of pure white kaolin which has been derived from the residual deposits of feldspathic rocks. These kaolin deposits are discussed in Chapter XIII. In some places the clay is very quartzose and is mixed with boulders and gravel. Beds of this character are very common and are usually not over four or five feet in thickness.

The following descriptions of the individual brick plants are intended to give a clearer idea of the deposits of clay and the methods of manufacture.

AMERY.

Amery is located on the Soo Railroad in the south central part of Polk County. The only brick yard at this place is located about one-half mile southwest of the depot and is owned and operated by **J. P. Peterson.** This yard was opened in 1881 and has been operated each year since that time.

The clay bank has a thickness of from three to five feet and extends over a considerable area. The color of the clay is blue, irregularly streaked with yellow iron oxide. It contains considerable quartz and burns red.

The clay is mixed in a wooden pug mill. The brick are moulded by hand, dried on pallets under sheds, and burned in scove kilns.

The yard is equipped with an Adrian brick and tile machine and a Quaker soft mud machine, neither of which were being used when the yard was inspected in 1899.

During the last three years the average annual output has been about 150,000. The brick sold in 1899 for about $4.50 per M. kiln run.

ANTIGO.

Antigo is located in the south central part of Langlade County on the Chicago and Northwestern Railroad. There are five brick yards in operation in this vicinity which are owned by **Edward Boetcher, Edward Grabowski, Keen Brothers, William Laehm, and Herman E. Meyer.** The clay which occurs at all of the yards is essentially the same and the methods of manufacture do not differ materially.

At **Grabowski's yard** the clay bank has a thickness of about three feet. The upper eight inches, which consists of black loam, is removed. Underneath the stripping the clay has a yellowish brown color streaked with blue. Below the clay granite gravel occurs to an unknown depth.

The clay is mixed in wooden pug mills operated by horse power. The brick are moulded by hand, dried on pallets under sheds, and burned in scove kilns. It requires seven days to burn the brick and about one-fourth of a cord of wood is consumed for each thousand brick burned.

This brick yard was opened in 1887 and has been operated each year since that time. The average annual output for the last three years has been about 150,000 brick. The brick were sold in 1899 for about $4.00 per M. kiln run.

Edward Boetcher's brick yard is located in the northwestern part of the city. The clay bank has a thickness of about two and one-half feet and passes below into granite gravel. The color of the clay is yellow streaked with blue. It is very quartzose and burns red.

The clay is soaked in a vat over night and mixed in a wooden pug mill. The brick are moulded by hand, dried on pallets under sheds, and burned in permanent up draft kilns.

This yard was opened in 1887 and has been worked each year since that time. During the last three years the average annual output has been about 120,000 brick.

The yard owned and operated by **Keen Brothers** is located in the southwest ¼ of Section 1, Town 30, Range 11 east.

The clay bank has a thickness of about twelve feet, only four or five of which are now used. The clay is mixed in a pug mill. The brick are moulded in a Reliable soft mud machine, dried under sheds, and burned in scove kilns. This yard was opened in the spring of 1897 and during the following year the output was about 200,000.

William Laehm's yard is about one-fourth of a mile west of that owned by Boetcher. The clay has a thickness of from one and one-half to two feet and is dug from between tree stumps which are scattered over the field. The color of the clay is yellowish brown streaked with blue.

The clay is soaked in a vat over night and then transferred to a Quaker soft mud machine in which the brick are moulded. The brick are dried on pallets under sheds and burned in scove kilns.

The brick yard owned by **Herman Meyer** is situated about one-fourth of a mile west of the city limits.

The clay bank has a thickness of about two and one-half feet underneath which gravel occurs. After soaking in a vat the clay is mixed in a wooden pug mill operated by horse power. The brick are moulded by hand, dried on pallets under sheds, and burned in scove kilns.

This yard was opened in 1887 and has been operated each year since that time. The average annual output of the yard is about 125,000 to 200,000. The brick sold in 1899 for about $5.00 per M. kiln run.

ATHENS.

Athens is located in the northwestern part of Marathon County on the Abbottsford and Northeastern Railroad. The only brick yard at this place is located about a mile north of the city and is owned and operated by **Carl Degner.** The clay occurs in a valley and is probably of alluvial origin. The clay is from four to seven feet deep and has a yellowish blue color resembling that which is mined at Antigo.

The clay is obtained from two different banks and mixed in definite proportions. It is soaked in a vat over night and then mixed in a wooden pug mill operated by horse power. The brick are moulded by hand, dried on pallets under sheds, and burned in a permanent up draft kiln. The color of the brick is red.

It requires about fourteen days to burn the brick and one-half of a cord of wood is consumed for each thousand brick burned.

This yard was opened in 1883 and has been operated each year since that time. The brick sold in 1899 for $7.00 per M. kiln run.

AUGUSTA.

Augusta is located in the southeastern part of Eau Claire County on the Chicago, St. Paul, Minneapolis, and Omaha Railroad. The only yard located at this place was opened about twenty-five years ago. It is now owned and operated by **E. W. Johnson.** In 1898, 350,000 brick were manufactured. Since that time the yard has been idle.

The clay occurs close to the factory and has a thickness of from two to two and a half feet. It has a blue color streaked with brown and yellow iron oxide. The clay is covered with one foot of loam which is mixed with the clay for the manufacture of brick.

The clay is soaked over night in a vat. The brick are made in an iron Quaker soft mud machine operated by horse power, dried on pallets under sheds, and burned in either permanent or scove up draft kilns.

The clay which occurs at this locality contains too great a percentage of sand to make a strong brick. About two or two and a half miles west of the city a yellowish brown residual or loess clay occurs, which is to all appearances much more suitable for the manufacture of brick than that which is being used. There are large quantities of this clay and I believe that better brick can be manufactured therefrom than are now being manufactured from the clay at Augusta.

BARRON.

Barron is located in the central part of Barron County on the "Soo" Railroad. The clay which is being used at **Carey's Brick Yard** has a reddish brown color and does not differ materially from the ordinary glacial clay found abundantly throughout this region. The field from which the clay is now being obtained contains a great many stumps and boulders. The surface is covered with from six to eight inches of loam which is stripped. The clay has a depth of from three to four feet, underneath which occurs an unknown depth of sand.

The clay is mixed in a vat over night, after which it is moulded in a Quaker soft mud machine operated by steam power. The brick are dried on pallets under sheds and burned in scove kilns. The color of the brick is red. An attempt is apparently made to burn all the brick hard but in so doing five or six tiers of brick above the arches are cracked and broken.

The shrinkage in burning is very little on account of the high percentage of quartz sand which the clay contains.

BARRONETT.

Barronett is situated in the northwestern part of Barron County on the Chicago, St. Paul, Minneapolis and Omaha Railroad. Two brick yards are located at this place, one of which is owned by **Martin Peterson** and the other by **Peter Larson.** The clay at this place has a maximum thickness of sixteen feet, although at the present time it is only worked to a depth of seven feet. The color of the clay is yellowish brown streaked with blue.

At **Peter Larson's** yard the brick are manufactured in an Anderson soft mud machine, dried on pallets under sheds, and burned in permanent up draft kilns. This yard is also equipped with a dry kiln having a capacity of about 15,000 brick.

It requires about six days to burn the brick, and about one-fourth of a cord of wood is consumed for each thousand brick burned. The average annual output of the yard is between 800,000 and 900,000 brick.

The yard owned by **Martin Peterson** has an equipment very similar to that of Larson's yard. The brick are manufactured in a Quaker soft mud machine, dried on pallets under sheds, and burned in up draft kilns.

BAY CITY.

Bay City is located in the southern part of Pierce County on the Chicago, Burlington and Northern Railroad. **The Bay City Brick Yard** is owned and operated by *Peter Miller.* The clay which is used at this place is very similar to the modified residual clay which occurs in all parts of the driftless area. The clay is obtained from a bank near the base of the bluffs along the Mississippi River. The clay contains an occasional limestone pebble and should therefore be worked very carefully. Otherwise it is of the ordinary residual type.

The clay is soaked over night in a vat and mixed in a wooden pug mill. The brick are made in a hand power press, dried in hacks on the yard, and burned in scove kilns.

This yard was opened in 1891 and has been operated each year since with the exception of 1895. During the last three years the average annual output of the yard has been in the neighborhood of 250,000. The brick sold in 1899 at prices ranging from $5.50 to $8.00 per M. kiln run.

CHIPPEWA FALLS.

Chippewa Falls is located on the Chicago, St. Paul, Minneapolis and Omaha and Wisconsin Central railroads in the southwestern part of Chippewa County. In 1899 the only brick yard at this place was owned and operated by **J. B. Theriault.** This yard is located in the town of Tilden near the city limits and was opened in 1890.

The bank from which the clay is obtained is situated near the base of the bluffs back from the Chippewa River and has a thickness of from four to eight feet. As in most of the clay banks of this area the clay is richest at the top, becoming more quartzose as the bottom is approached. The clay in the upper part of the bank is massive but that comprising the lower five feet is thinly laminated with streaks of white sand. The clay has a reddish brown color and burns red. The sand used in moulding is obtained underneath the clay and has a depth of about seven feet above the sandstone with which it is underlain.

The clay is mixed in a pug mill. The brick are moulded in a Craycroft soft mud machine, dried on pallets under sheds, and burned in scove kilns.

This yard is in excellent condition and has a very competent superintendent. A number of very clever devices have been constructed to save labor in the manufacture of the brick. The brick which were examined at the yard were among the best common brick which are made in this area.

Laboratory Examination.—The clay was examined in the Survey laboratory. It is of medium hardness when dry and slacks readily in water breaking down into a finely pulverulent mass which has a fair degree of plasticity.

Under the microscope the grains were observed to have diameters ranging from .10 mm. to .003 mm. A very small percentage of the individuals are less than .0058 mm. in diameter. The larger grains are fairly well rounded but the smaller ones have angular outlines.

The clay is deeply stained with iron oxide and contains a large percentage of quartz. Kaolin constitutes a very small proportion of the mass. The chemical composition of the clay is given in table I of the Appendix.

A number of years ago the **French Lumber Company** manufactured brick a short distance from the yard now being operated by *Mr. Theriault.* The brick were manufactured in a soft mud machine, dried on pallets under sheds, and burned in scove kilns. The clay was not examined but it is thought to be about the same as that occurring at Theriault's yard.

COLBY.

Colby is located in the eastern part of Clark County on the Wisconsin Central Railroad. The only brick yard which is located at this place is owned and operated by **Joseph Haslbeck.** The yard is situated in the south part of the city and not far from the railroad. The clay bank has a thickness of from three to four feet. The color of the clay is blue mottled with streaks of yellow. The clay is mixed in a wooden pug mill. The brick are moulded by hand, dried in hacks on the yard, and burned in scove kilns.

The brick have a red color and vary considerably in hardness in different parts of the kiln.

The output of the yard in 1898 was about 100,000. The brick sold at the yard in 1899 for about $7.00 per M. kiln run.

CONOVER.

Conover is located on the Chicago and Northwestern Railroad in the northeastern part of Vilas County. The plant which is located at this place is known as the **Eagle River Brick Yard** and is owned and operated by a company of which N. A. Coleman is secretary.

The bank from which the clay is obtained has a thickness of from five to eight feet. The upper two or three feet consists mainly of yellow sand, underneath which occurs from one and one-half to two feet of laminated red clay, two feet of grayish colored clay, and an undetermined thickness of sand. The upper surface of the clay is uneven and billowy on account of which the thickness of the bed is quite variable. The brick are manufactured in a Big Wonder auger machine, dried on pallets under sheds and in hacks on the yard, and burned in scove kilns. It requires about fourteen days to burn the brick, green wood being used for fuel. The clay burns red.

This plant was erected in 1898 and has been operated each year since. During 1898 the company manufactured in the neighborhood of 300,000 brick which sold at the yard for about $8.00 per M. kiln run.

DORCHESTER.

Dorchester is located in the northeastern part of Clark County on the Wisconsin Central Railroad. North of this village in the northwestern part of Section 1, Town 29, Range 1 east, is a small plant which is owned and operated by **J. M. Fisse.** The bank from which the clay is taken has a thickness of about three feet and the clay is very similar in appearance to that which occurs at Colby, with the exception that it contains many small granitic pebbles. The brick are moulded in a hand press machine, dried in hacks on the yard, and burned in scove kilns. It requires about eight days to burn the brick, and about one-third of a cord of wood is consumed for each thousand brick burned. The brick have a bright red color and when properly burned they are very satisfactory.

This yard was opened in 1885 and has been operated each year since that time. The average annual output is about 60,000. The brick sold in 1899 at an average of $7.00 per M. kiln run.

DURAND.

Durand is located on the Chippewa River in the south central part of Pepin County. The only brick yard at this place is located about one mile east of the city and is owned and operated by **J. T. Dorchester.** The clay which is being used is hauled from the top of bluffs about half a mile south of the plant. It is a yellow sandy clay, similar to the residual limestone or loess clays previously described. The clay is mixed on a board platform adjacent to a horizontal Potts soft mud machine in which the brick are moulded. The brick are dried on pallets under sheds and burned in scove kilns. It requires two weeks to dry the brick and eight days to burn them. One-third of a cord of oak wood is consumed for each thousand brick burned.

A shale which occurs interlaminated with the sandstone of the Potsdam formation at this place has been tested by Mr. Dorchester and is thought by him to be suitable for manufacturing fire brick. The writer has not examined the clay and no statement can be made relative to the same.

EDGAR.

Edgar is located in the west central part of Marathon County on the Chicago and Northwestern Railroad. Two brick yards are located at this place, one of which is owned by the **Edgar Brick and Tile Company** and the other by **the Edgar Pressed Brick Company.**

The plant of the **Edgar Pressed Brick Company** has been operated for the last three years. The equipment is in good condition and consists of four large kiln sheds having a capacity of about two million brick, pallet sheds having a capacity of about 350,000 to 400,000 brick, three pug mills, and a Frey-Sheckler stiff mud machine.

The clay occurs near the creek but could not be examined at the time the yard was inspected on account of the water which filled the pits. The brick when properly burned have a cheerful red color.

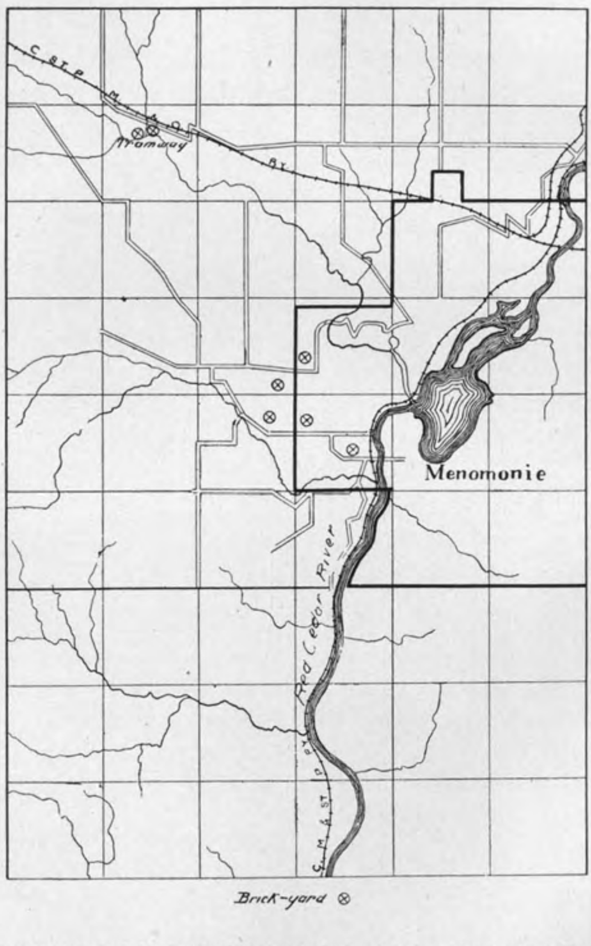
The plant of the **Edgar Brick and Tile Company** was erected in 1897. The bank from which the clay is obtained consists of one foot of loam which is stripped, one foot of tough grayish black clay, and one to one foot and a half of blue clay mottled with streaks of yellow iron oxide.

The clay is conveyed in dump cars from the bank to the plant and tempered in a Potts wooden pug mill. The brick are moulded in a Potts soft mud machine, dried on pallets under sheds, and burned in scove kilns. It requires about fourteen days to burn the brick and about three-fourths of a cord of wood is consumed for each thousand brick burned. When properly burned the brick have a pleasing red color.

EDSON.

Edson is a small village located in Chippewa County two and a quarter miles south of Boyd. The yard at this place has been owned and operated for five years by **J. T. Somers** but at the present time it is idle. The clay, which occurs in a depression in which runs a small sluggish stream, has a depth of about four feet underneath a covering of one foot of sod and loam. The color of the clay is blue streaked with yellow iron oxide wherever roots of grass or trees have penetrated. The clay contains considerable sand as it occurs in the bank but more is added for the manufacture of brick. This clay is typical for all this region.

The clay is mined with pick and shovel and hauled in carts to vats where it is soaked. The brick are made in a Quaker soft mud machine, dried on pallets under sheds and burned in scove kilns. The market for the brick which



SKETCH MAP SHOWING LOCATION OF THE BRICK YARDS AT MENOMONIE.

are manufactured at this place is entirely local and the yard will probably not be operated until there is an increased demand.

ELLSWORTH.

Ellsworth is located in the central part of Pierce County on the Chicago, St. Paul, Minneapolis, and Omaha Railroad. The only brick yard at this place is located about one mile and a half southwest of the city and is owned and operated by **C. I. Peterson.** The yard was opened in 1887 and has been operated continuously since that time with the exception of two or three years.

The clay has a thickness of from two to two and a half feet. The color is a yellowish brown, resembling very much the residual or loess clay of the driftless area. The bank is plowed and the clay weathered before being used. When used it is soaked in a vat and then pugged in a brick machine. The brick are moulded in a Quaker soft mud machine operated by horse power, dried on pallets under sheds and in hacks on the yard, and burned in scove kilns. When properly burned the brick have a bright red color. However, the sand which is used in moulding gives the brick a grayish color which may be partly due to a small percentage of calcium carbonate in the sand. The average annual output of this yard during the last three years has been about 500,000 brick. The brick were sold at the yard in 1889 for $5.00 per M. kiln run.

GLENWOOD.

Glenwood is located in the west central part of St. Croix County on the Wisconsin Central Railroad.

The Glenwood Brick Yard is owned and operated by **Syme, Baldwin and Company.** It was opened during the summer of 1900 and during that season 200,000 brick were manufactured.

The clay is of a rich yellow nature and burns an excellent red color. The clay is mined with pick and shovel and transferred from the bank to the machine on cars. The brick are manufactured in a "Standard" sand mould machine which has a capacity of 24,000 brick per day. The brick are dried in hacks on the yard and burned in common scove kilns.

This company contemplates increasing the capacity of the plant to 5,000,000 brick annually.

HAMBURG.

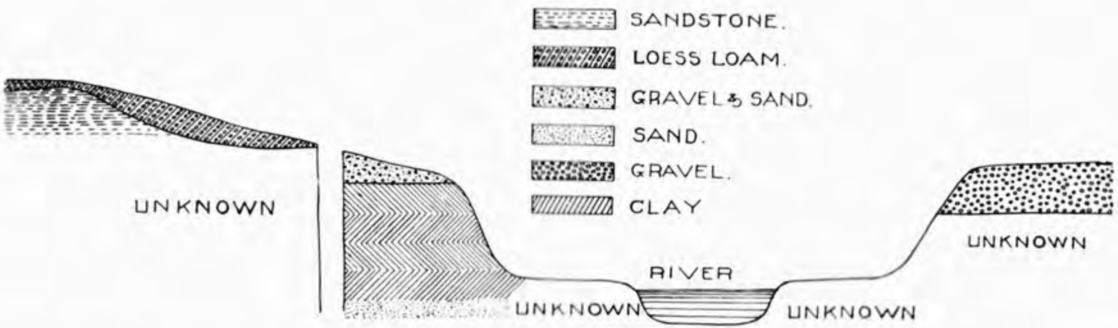
Hamburg is located in Marathon County in Section 28, Town 30, Range 5, East. The only brick yard operated at this place is owned by **John A. Amen and Company.**

The bank from which the clay is obtained has a thickness of from two to four feet and an area of about three-fourths of an acre. The clay contains numerous granite pebbles. It is mined with picks and shovels and mixed in wooden pug mills. The brick are moulded by hand, dried on pallets under sheds, and burned in scove kilns. The output of this yard in 1899 was about 200,000 brick.

LOYAL.

Loyal is located on the Wisconsin Central Railroad in the east central part of Clark County. The only brick yard at this place is owned and operated by **C. Buhlman.** The bank from which the clay is obtained consists of one foot of sod and soil which is stripped, from three to six feet of blue clay streaked with yellow, and ten feet of blue clay, underneath which is sand. The clay contains an occasional granite pebble which, however, does not seriously impair the value of the clay. In places at the surface there is a tough black clay which when mixed with that which occurs underneath causes the brick to crack in drying. Black clay similar to this occurs in many parts of this region and is always avoided on account of the tendency which brick made therefrom have of cracking when drying.

The clay is soaked in vats and mixed in pug mills operated by horse power. The brick are moulded in a hand



IDEAL SECTION SHOWING THE RELATION OF CLAY DEPOSITS TO THE OTHER FORMATIONS IN THE VICINITY OF MENOMONIE, DUNN COUNTY.

press, dried in hacks on the yard, and burned in scove kilns. The brick have a red color. It requires from ten to eleven days to burn and about one-third of a cord of wood is consumed for each thousand brick burned.

This yard was opened in 1896 and has been operated each year since that time. The average annual output during the last three years has been about 250,000 brick. The brick sold at the yard in 1899 for about $5.00 per M. kiln run.

The brick yard owned by the **York Brick Company** is located about five miles south of Loyal in Clark County. The bank from which the clay is obtained has an average thickness of two and one-half feet. The clay has a bluish color and is streaked with yellow iron oxide. After removing the clay from the bank it is soaked in a vat over night. The brick are moulded in a soft mud machine, dried on pallets under sheds and in hacks on the yard, and burned in scove kilns. It requires from eight to nine days to burn the brick and about one-half of a cord of wood is consumed for each thousand brick burned.

MARSHFIELD.

Marshfield is located in the northwestern part of Wood County on the Chicago and Northwestern and Wisconsin Central Railroads. For a number of years two brick yards have been operated near this city but at the present time only the **Central Wisconsin Pressed Brick Company** is in operation. Lyons, Reese, and Lyons are the proprietors of this company, T. F. Lyons is secretary and J. D. Pratt is superintendent.

The bank from which the clay is obtained is about three hundred feet from the machine and consists of six inches of black tough clay at the surface, six to eight inches of quick sand, two to two and a half feet of greenish gray clay, two to four feet of blue clay streaked with yellow, six inches of gravel, and forty feet of blue clay. When the works were examined in 1899 from six to seven feet of the clay down to the gravel bed was being worked. The blue clay below the gravel bed contains streaks of red iron oxide in sufficient quantity to give the brick when burned a deep red color.

The clay is conveyed to the factory on cars operated by rope and winding drum and mixed in the machine. The brick are manufactured in a Quaker soft mud machine, dried on pallets under sheds,and burned in scove kilns. It requires about nine days to burn the brick and about one-third of a cord of wood is consumed for each thousand brick burned.

This yard was opened in 1887 and has been operated each year since that time. The present company, however, have had control only since 1899. During the four years prior to 1900 the output of the yard was in the neighborhood of 500,000 brick per year. In 1900 the output reached one million and a half.

With the exception of the clay occurring at three or four other localities the Marshfield clay differs very materially from that which is worked in other parts of this area.

Laboratory Examination.—Three samples of the clay from different parts of the bank were examined in the laboratory. Each slacked rapidly breaking down into very fine granular masses which were uniform in texture and moderately plastic. When mixed with water the three samples had very few macroscopic characteristics to distinguish them apart.

Under the microscope they also appear very much the same. The largest grains observed were about .11 mm. in diameter. A greater part of the clay consists of grains which have diameters of less than .012 mm. in diameter. One of the samples is composed of grains which average less. A small percentage of the clay consists of grains .001 mm. and less in diameter. The grains are mainly sub-angular in outline, only a few of the larger ones being well rounded.

Quartz is the principal constituent. Iron oxide and

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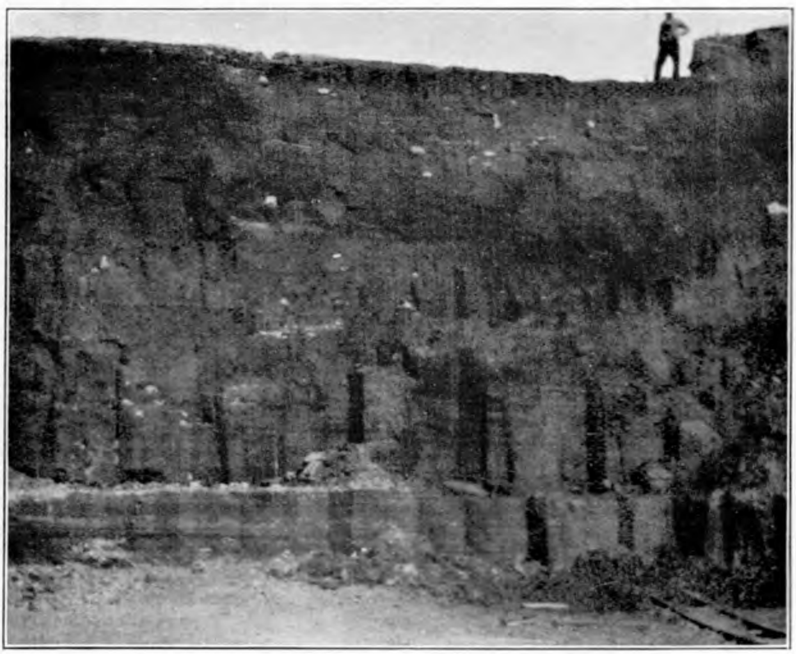


2

THE WISCONSIN RED PRESSED BRICK CO., MENOMONIE.

VIEWS OF CLAY BANK.

kaolin occur in lesser amounts, while an occasional grain of calcite can be recognized. The chemical composition of the clay is given in table I of the Appendix, to which the reader is referred. From the composition there given and the evidence derived from the physical examinations as thus far conducted, I believe that it is worth while to consider this clay for the manufacture of clay wares other than brick.

MEDFORD.

Medford is located on the Wisconsin Central Railroad in the southeastern part of Taylor County. The only brick yard in this vicinity is located about three and a quarter miles north of the city. It is owned and operated by **Otto Fischer.** The plant was erected in 1897 and has been operated each year since that time.

The clay has a thickness of thirteen or fourteen feet but only the upper three feet is now being used. The clay which occurs deeper in the bank contains a less percentage of quartz and consequently the brick made therefrom dry more slowly than those made from the surface clay.

The clay is soaked in a vat over night and mixed in a pug mill operated by horse power. The brick are moulded in a hand press, dried in hacks on the yard, and burned in scove kilns.

During the last three years the average annual output has been 250,000. The brick were sold in 1899 for $6.00 per M. kiln run at the yard.

MENOMONIE.

Menomonie is located in the central part of Dunn County on the Chicago and Northwestern and Chicago, Milwaukee, and St. Paul Railroads. Since brick making began at this place at least five different plants have been in operation. At the present time, however, these yards are all controlled by two companies, known as the **Me-**

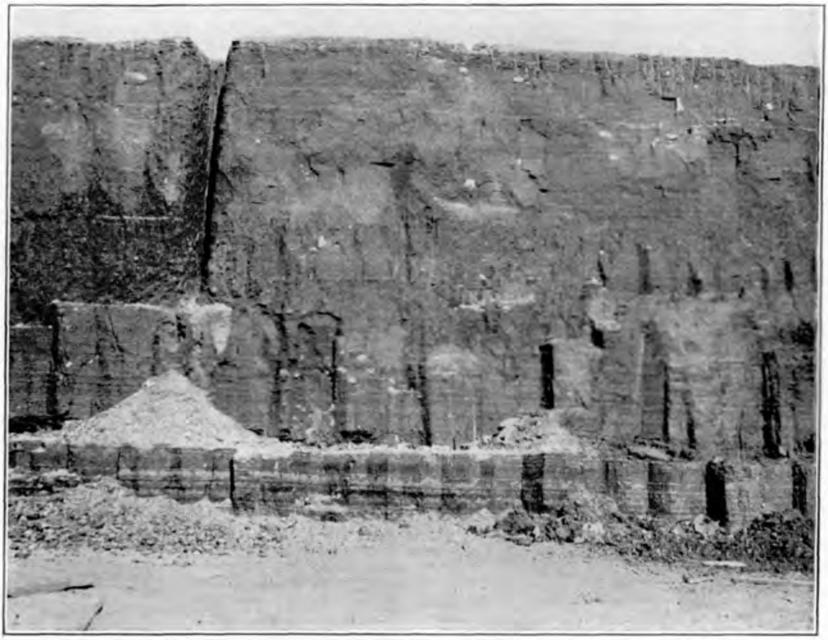
nomonie Hydraulic Pressed Brick Company and the **Wisconsin Red Pressed Brick Company.**

The Wisconsin Red Pressed Brick Company own and operate a single yard located directly west of the city and on the west side of the Red Cedar River. **The Menominie Hydraulic Pressed Brick Company** own four yards, only three of which are being operated at the present time. Another yard known as the Standard was abandoned several years ago on account of a scarcity of clay and it is practically of no value at the present time.

The plant of the **Wisconsin Red Pressed Brick Company** is owned by a Minneapolis Company, and operated by *N. M. Sargent* and *I. M. Phillips*, the latter of which is the superintendent of the yard. This yard was opened in 1885 and has been operated each year since that time. At present the brick are all manufactured by the soft mud process, although an attempt was made several years ago to use a dry press machine.

The bank from which the clay is obtained has a stripping of five to eight feet of sand and gravel, underneath which occurs a thickness of thirty-six feet of clay, and an unknown depth of sand. The clay occurs in layers which are from one to twelve inches in thickness. Each layer is separated from the one above and below by thin laminae of sand. The thickness of these laminae increases as the bottom of the bank is approached until the bank becomes mainly sand.

The bank is divided according to the color of the clay into two parts. The part comprising the upper two feet and a half of the bank contains layers of clay which have a deep red color and is known as the red clay. The remainder of the bank contains very few red layers and is known as the blue clay. A close inspection of the different layers in the lower part of the bank shows that they are mainly blue, green, and yellow, with only an occasional red colored laminae. The red and blue portions of the bank, as well as the blue clay and sand layers underneath gradu-



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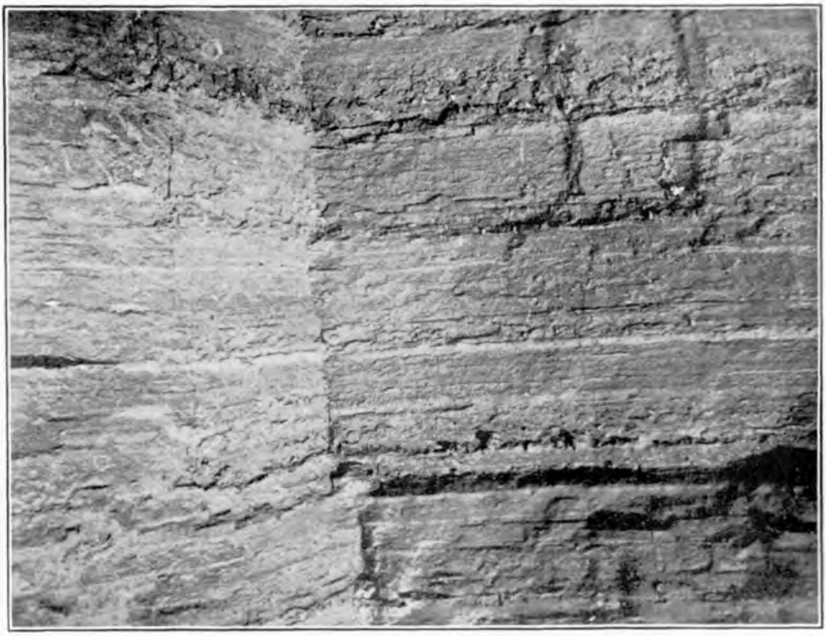


2

WISCONSIN RED PRESSED BRICK CO., MENOMONIE.

NEAR VIEWS OF CLAY BANK SHOWING JOINTING PLANES.

ally grade into one another. The bank is traversed by distinct sets of joints on account of which the clay breaks away from the bank in large polygonal blocks.

The clay bank is worked by digging a trench back from the face of the bank and filling it with water. The water loosens the blocks and they fall in a heap at the foot of the bank. The clay is conveyed from the bank to the mill on cars operated by cable and winding drum. The clay is mixed and tempered by passing it through three pug mills. The brick are made in a Monarch soft mud machine, dried on pallets under sheds, and burned in permanent up draft kilns. It requires about one hundred car loads of clay to make 50,000 brick. The capacity of the pallet sheds is about 500,000 and that of the kilns something over one million.

The average annual output of the yard during the last three years has been in the neighborhood of five million brick. The average price of the brick in 1899 was $4.00 per M. kiln run at the yard.

For a number of years Mr. Phillips has been considering the manufacture of paving brick out of this clay. The brick about the arches of the kilns are frequently well vitrified, making excellent brick for sidewalk purposes. This, combined with the fact that similar clay from a neighboring yard has been tested for the manufacture of paving brick and reported to be suitable, has led to the belief that paving brick can be successfully manufactured. There is no doubt that the brick can be vitrified but the most important point which has not yet been settled, is whether an entire kiln of brick can be thoroughly vitrified without excessive loss. Until the laboratory tests with this clay have been completed nothing positive can be said concerning this point.

Laboratory Examination.—The samples of clay examined in the laboratory were soft both in the wet and dry state. All of the samples slacked very readily in water, breaking down into flakes and fine grains, forming a moderately plastic mass.

Under the microscope the clay was seen to consist of grains not exceeding .014 of a mm. in diameter and ranging from this down to less than .001 mm. The top clay consists of grains which were on an average about .003 mm. in diameter. The other two samples examined consist mainly of individuals ranging in size from .0058 to .003 mm. in diameter. With the exception of the largest grains the individuals are very irregular in outline and unequi-dimensional in size.

Quartz is an abundant constituent of the clay. The quantity of iron oxide which occurs as a staining agent is comparatively small except in the red colored layers. The green colored layers contain a chloritic mineral which imparts to the clay the distinguishing green or bluish color.

The thin sandy seams which separate the layers of clay consist of grains which are uniformly much larger than those of the clay layers. Numerous measurements show that the large grains of quartz in this layer have a diameter of from .33 to .20 mm. The chemical composition of this clay is given in table I of the Appendix.

The Menomonie Hydraulic Pressed Brick Company own four of the brick plants situated in the vicinity of Menomonie. These plants were formerly known as the Northern Hydraulic Pressed Brick Co., two yards, known as No. 1 and 2; the Menomonie Pressed Brick Yard, now known as No. 3; and the J. K. Caldwell Brick Yard, known as No. 4. At the present time the yards numbered 1, 2 and 3 are the only ones which are operated. At the No. 3 yard only soft mud brick are manufactured. At the No. 1 and 2 yards both soft mud and dry press brick are made.

The clay bank which occurs at the yard formerly owned by the Menomonie Pressed Brick Company has a depth of from nine to eleven feet. The upper portion of the bank is moderately rich but the lower four or five feet is very sandy. The clay has a yellowish brown color and is thinly laminated. It is conveyed from the bank to the mill on dump cars operated by steam power and cable. The brick are manufactured in two Eagle soft mud machines, having a capacity of 50 M. each per day, dried on pallets under sheds, and burned in permanent up draft kilns.

At the No. 1 and 2 yards one bank of clay is worked. The clay used for manufacturing dry pressed brick is obtained from a bank having a thickness of from seven to eight feet. The clay has a yellowish brown color and resembles the residual clay which is found abundantly throughout the driftless area. The clay is plowed and weathered before being hauled under the sheds. As the clay dries at the surface it is collected with wheeled excavators and conveyed under sheds. For the manufacture of some mottled brick, clay has been obtained from other points. The brick are manufactured in hydraulic machines and burned in kilns designed and constructed by the company owning the yard.

When taken from the kiln the red dry press brick are carefully sorted into ten different shades so that one can readily obtain any desired quantity of brick, all of which will have the same tint. The company also manufacture 410 special shapes of brick of almost every staple design.

The reddish brown clay which is used in the manufacture of the dry press brick occurs at a higher level than the laminated clay and has a very limited areal extent in this region. It covers the upper portion of the sandstone knolls and is more distant from the river than the laminated deposits.

The No. 2 yard is equipped with a Henry Martin soft mud machine and pallet sheds which are used for the manufacture of veneering brick. Laminated clay similar to that mined at the other yards is used for this purpose. The capacity of the pallet sheds on No. 2 and 3 yards is in the neighborhood of 1,800,000, and the kiln capacity is about 3,800,000. The average annual output of the three yards is in the neighborhood of 12,000,000 veneering brick and 5,000,000 pressed brick. Common brick sold in 1899 at an average of about $4.50 per M. kiln run. Veneering, sand moulded brick sold at an average of about $9.00 per M. Pressed brick sold at an average of about $14.00 per M.

The clay which occurs at the Caldwell yard, which has been lately acquired by the Menomonie Hydraulic Pressed Brick Company, is thinly laminated and appears very similar to that which is being worked by the Wisconsin Red Pressed Brick Company. The layers are interlaminated with very thin laminae of comparatively coarse sand. The upper portion has a general reddish brown color while the lower is a bluish green. The layers are from one-sixteenth of an inch to several inches in thickness. The clay has a maximum thickness of twenty-two feet below which occurs an unknown depth of sand. At the place examined the bank was exposed to a depth of about thirteen feet.

The clay in this vicinity is essentially free from gravel. Occasionally a granite or greenstone pebble is met with but there is no evidence of limestone.

Extensive deposits of clay similar to, although not identical with, that which occurs at the Caldwell and Wisconsin Red Pressed Brick Company's yards are found at several places along the tributaries of the Red Cedar River. The clay is of alluvial origin having been derived from the disintegrated igneous rocks to the north and northwest. They are essentially non-calcareous and are among the best brick making clays occurring in the area under discussion.

MERRILL.

Merrill is located in the southeastern part of Lincoln County on the Chicago, Milwaukee and St. Paul Railroad. Two brick yards are operated at this place, one of which is owned by **Herman Boetcher** and the other by **August**

Meyer. The clay which occurs at these yards has an average thickness of about three feet. About one foot of black loam is stripped from the surface underneath which occurs two to two and a half feet of yellowish brown clay. In some places the clay contains small pockets of granite gravel. The brick made at both yards are known as "slop" brick.

The yard owned by **Herman Boetcher** was opened in 1876. The clay is soaked in a vat and mixed in a wooden pug mill operated by horse power. The brick are moulded by hand, dried on pallets under sheds, and burned in scove kilns. The average annual output is about 275,000 common red brick. The brick sold on the market in 1899 for $5.25 per M. kiln run.

The brick yard owned and operated by **August Meyer** is located across the road from Boetcher's yard. The clay is soaked in a vat and mixed in a wooden pug mill. The brick are made by hand, dried on pallets under sheds, and burned in scove kilns.

It requires from eight to nine days to burn the brick and about one-half cord of wood is consumed for each thousand brick burned.

MERRILLAN.

Merrillan is located in the north central part of Jackson County at the junction of the Chicago, St. Paul, Minneapolis, and Omaha and Green Bay and Western Railroads. Only one brick yard has been located at this place and this has not been operated for several years. The yard is situated about two and a half miles north of the city and is owned by **Frank Robertson.**

The clay occurs on low land adjacent to a small stream and has a thickness of from three to four feet. It is probably of alluvial origin. The clay is fine grained, smooth, and moderately plastic. The clay has a yellowish blue color and resembles in all respects the ordinary glacial clay which occurs throughout this region.

The clay is soaked in vats and mixed in wooden pug mills operated by horse power. The brick are moulded by hand, dried in hacks on the yard, and burned in scove kilns.

The yard was opened in 1889 and was operated each year until 1898, since which time it has been idle.

MILLTOWN.

Milltown is located near the north central part of Polk County and some distance from any railroad. The only brick yard in this vicinity is owned and operated by **Lud Peterson.** The clay bank which is being worked has a thickness of about fifteen feet. It consists of a stripping of three to four feet of sand and gravel and from ten to twelve feet of laminated reddish brown clay. The clay is mixed in a pug mill and the brick are manufactured in a machine which was made by the owner of the yard. The brick are dried on pallets under a shed and in hacks on the yard and burned in scove kilns. It requires from eight to nine days to burn the brick.

This yard was opened in 1897 and has been operated each year since that time. During the last three years the average annual output has been in the neighborhood of 60,000 brick.

NEILLSVILLE.

Neillsville is located in the south central part of Clark County on the Chicago and Northwestern Railway. **A. W. Schoengard** owns and operates the only brick yard in this vicinity. The clay which is mined has a depth of six to eight feet and a general yellowish blue color. It is soaked in a vat over night and mixed in a wooden pug mill which is operated by horse power. The brick are made in a Quaker soft mud machine, dried on pallets under sheds, and burned in scove kilns. It requires about nine days to burn the brick, and about one-half of a cord of wood is consumed for each thousand brick burned. The color of the brick is red.

This yard was opened in 1884 and has been operated each year since that time. The average annual output during the last three years has been about 300,000. The brick sold in 1899 at an average of $5.00 per M. kiln run at the yard.

OSCEOLA.

Osceola is located in the western part of St. Croix county on the "Soo" railroad. The only brick yard at this place is located eight miles south of the city and is owned and operated by **Charles Englehart.** The yard was opened in 1890 and has been operated each year since that time with the exception of 1891 and 1895.

The clay has a thickness of eighteen to twenty feet. The upper two to four feet is much richer than the sixteen feet which occurs below. The lower portion of the bank contains a large percentage of sand and numerous small, granite pebbles. The brick are made in a Quaker soft mud machine, dried in hacks on the yard, and burned in scove kilns. It requires about seven and a half days to burn the brick and about one-third of a cord of wood is consumed in burning each thousand brick. During the last three years the average annual output has been 50,000 brick. The brick sold at the yard in 1899 for $6.00 per M. kiln run.

NEW RICHMOND.

New Richmond is located in the eastern part of St. Croix county. The only brick yard at this place is situated one and a half miles west of the city. This yard has been owned and operated by **E. Brevold** for sixteen years. The clay which is mined is covered with a foot of black loam and has a thickness of from four to fourteen feet. It has a general blue color, streaked and mottled with yellow. The clay is taken from the bank and weathered for a week or two after which it is soaked over night in a vat. The clay is removed from the vat and tempered in a pug mill operated by horse power. The brick are moulded in an "Old reliable" hand press machine, dried in hacks on the yard, and burned in scove kilns. The brick are strong and of good quality when properly burned, although somewhat irregular in shape owing to the method of manufacture.

PLUM CITY.

Plum City is located in the southeastern part of Pierce county nine miles from the nearest railroad. The brick plant at this place is owned and operated by **Nicholas Oberding.** The yard was opened in 1884 and has been operated each year since with the exception of 1899 and 1891.

The bank from which the clay is obtained has a total thickness of six and a half feet. A stripping of a foot and a half of black loam and soil occurs at the top, underneath which is a thickness of five feet of clay. The deposit is near Plum creek and is probably of alluvial origin. The brick are moulded by hand, dried on pallets under sheds, and burned in scove kilns. The brick have an excellent red color although the white sand used in moulding imparts a grayish tint to the surface. The average annual output of this yard during the last three years has been in the neighborhood of 100,000 brick. The market for the brick is entirely local. In 1899 they sold at prices ranging from $7.00 to $8.00 per M. kiln run at the yard.

RICE LAKE.

Rice Lake is located on the Chicago, St. Paul, Minneapolis and Omaha railroad in the north central part of Barron county. The only brick yard at this place is situated about a mile north of the city and is owned by **Mr. Skilper.** It was operated in 1899 by J. Mitchell. The clay has a depth of from one to five feet and is covered at the surface with a foot of black loam. The brick are manufactured in

THE TOMAHAWK BRICK YARD, TOMAHAWK.

a Quaker soft mud machine, dried on pallets under sheds, and burned in scove kilns. The color of the brick is red.

RIVER FALLS.

River Falls is located in the western part of Pierce county, on the Chicago, St. Paul, Minneapolis, and Omaha railroad. The only brick yard at this place is located one mile south of the city and is owned and operated by **George H. Smith.** The clay bank is said to have a total thickness of thirty-six feet of which ten feet is yellow clay and twenty-six feet blue clay. The portion of the bank which was open at the time the yard was inspected exposed a thickness of from six to eight feet of yellowish blue clay. The deposit appears to be of alluvial origin.

Sand is added to the clay which occurs in the upper portion of the bank and the whole is mixed together in a pug mill. The brick are made in a Quaker soft mud machine, dried on pallets under sheds, and burned in an up draft permanent kiln.

This yard was opened in 1896 and has been operated each year since that time. The average annual output during the last three years has been from 400,000 to 800,000. The brick sold in 1899 for $6.00 per M. kiln run at the yard.

The clay which occurs at this place is better than the average clay of this region. The brick if properly burned ought to have a cheerful red color and be sufficiently strong for all ordinary building purposes. The chemical composition of the clay from this bank is given in table I of the Appendix.

ST. CROIX FALLS.

St Croix Falls is located in the western part of Polk county on the "Soo" railroad. The only brick yard at this place is situated about two and one-half miles east of the city and is owned and operated by **August Dombrook.** The clay has a thickness of about six or seven feet. It is laminated, has a brown color, and is richest near the top of the bank. The clay is soaked in a vat over night, and then passed through a pug mill. The brick are moulded in a foot press, dried in hacks on the yard, and burned in scove kilns. The average annual output of the yard during the last three years has been about 100,000. The price of the brick at the yard averaged $7.00 per M. kiln run in 1899.

SCHULTZ SIDING.

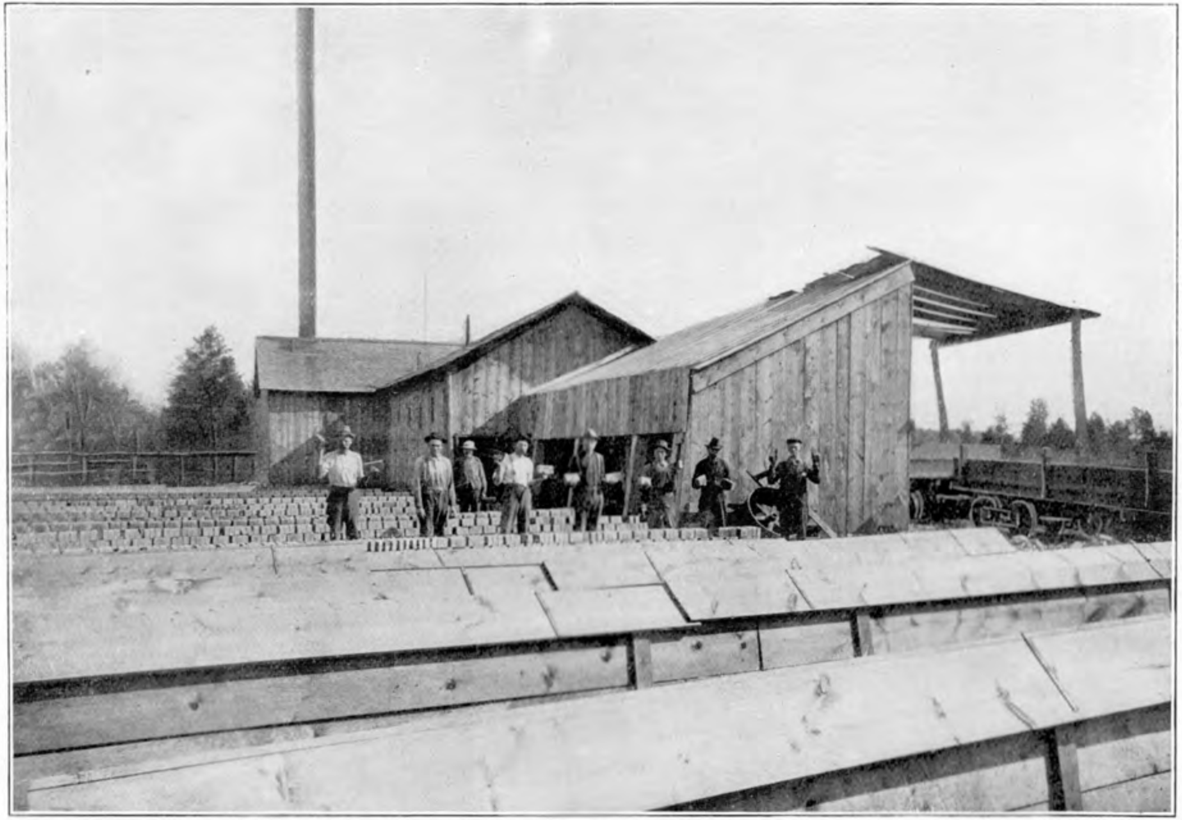
Schultz Siding is located in Lincoln county about eight miles north of Merrill. The brick plant located at this place is owned and operated by **J. H. Schultz.** It was opened in 1899 and has been operated each year since that time. The clay bank is four feet deep and consists of a stripping of one foot of loam and sod, one foot of heavy grayish blue clay, and two feet of yellow clay which passes gradually into sand below. The brick are manufactured by hand, dried on pallets under sheds, and burned in permanent up draft kilns.

During the last three years the average annual output of the yard has been 125,000. The average price of the brick in 1899 was $5.00 per M. kiln run.

SPENCER.

Spencer is located in the southwestern part of Marathon county on the Wisconsin Central railroad. Two yards are located in the vicinity of this village, one of which is owned by **Charles Stoltenow** and the other by **William Baedeker.**

The Stoltenow Brick Yard is situated at the west end of the village. The clay has a working depth of about five feet, is of a yellowish blue color and burns red. A blue clay which also burns red occurs a short distance north of the plant. The clay is mined with a pick and shovel and soaked in a vat over night. The brick are moulded in a soft mud machine, dried in hacks on the yard, and burned in scove kilns. This yard was opened in 1887 and has been operated each year since that time. The average annual



THE TOMAHAWK BRICK YARD, TOMAHAWK.

NEAR VIEW OF FACTORY SHOWING EMPLOYEES.

output during the last three years has been about 200,000 brick. The market price in 1899 was $6.00 per M. kiln run.

The plant owned by **William Baedeker** is located about three miles north of Spencer and is close to the Wisconsin Central railroad. The clay is very similar to that which occurs at Stoltenow's yard. The brick are moulded by hand, dried in hacks on the yard, and burned in scove kilns. The color of the brick is red. This yard was opened in 1898 and the output during that year was 150,000.

TOMAHAWK.

Tomahawk is located in the north central part of Lincoln county on the Wisconsin river. The works of the **Tomahawk Brick Manufacturing Company** are located in the eastern part of the city. The clay which is being used occurs eight miles distant and is hauled to the plant on the Marinette, Tomahawk, and Western railroad. The brick plant and clay banks are owned by **W. H. Bradley.** W. E. Jeannot is superintendent. The bank from which the clay is obtained occurs adjacent to the railroad and consists of about twelve feet of clay interstratified with layers of coarse sand which contains an occasional pebble of igneous rock. As far as could be ascertained no limestone occurs in this vicinity. The bank is streaked or laminated with thin red layers of clay although the greater part of the clay has a general pinkish gray color. The clay appears to be somewhat arenaceous in character. It is not very well exposed in the bank but according to borings made in this vicinity there is an unlimited quantity close to the railroad.

The clay is either mixed with sand or used as it comes from the bank depending upon its richness. The brick are manufactured in a Brewer Auger machine. The clay is so thoroughly mixed and tempered that there is no evidence of lamination in the brick when dried. The machine is equipped with a side cut off and the brick manufactured have an excellent appearance. The brick are handled twice in hacking but the fingers are not allowed to touch the faces or ends of the brick.

The yard is to be equipped in the near future with a Raymond re-press and permanent kilns for burning the brick. The machinery is run with a stationary engine.

At present the brick are dried in hacks on the yard and burned in scove kilns.

This yard was opened during the summer of 1900 but up to the present time only 200,000 brick have been burned. The color of the brick is red.

TRAMWAY.

Tramway is located near the central part of Dunn county on the Chicago, St. Paul, Minneapolis, and Omaha railroad. Until 1898 two brick yards have been operated at this place, one of which was erected by the East Tramway Brick Company and the other by the St. Paul Brick and Tile Company. The property of the latter company has been purchased by the Menomonie Hydraulic Pressed Brick Company and the machinery removed.

The East Tramway Brick Yard, which is owned by *Mrs. S. J. Kirkland,* is the only one being operated at the present time. This yard was opened in 1884 and has been operated eleven or twelve years since that time. The bank from which the clay is obtained has a thickness of about twenty-six feet, and consists of from three to four feet of coarse sand at the surface, six feet of sandy clay, two to two and a half feet of banded red clay, six to eight inches of blue clay, and thirteen feet of reddish blue clay. Underneath the clay occurs an unknown depth of sand. The red color of the clay in the upper portion of the bank is due to the oxidation of chloritic minerals similar to those which occur in the layers below. The clay in this bank is very similar to that which is being worked by the Wisconsin Red Pressed Brick Company at Menomonie. The clay occurs in thin layers which are separated from one another by

THE TOMAHAWK BRICK YARD, TOMAHAWK.

KILN SHED AND BRICK DRYING IN HACKS ON THE YARD.

thin laminae of sand. The bank is intercepted by numerous jointing planes which break the clay into large polygonal blocks. Ripple marks were observed between the beds of clay. The brick are made in an Anderson Chief soft mud machine, dried in a compartment steam drier and on pallets under sheds, and burned in scove kilns.

The brick made at this yard do not differ materially from the sand moulded brick made at Menomonie. When well burned they have a deep red color. However, the white sand which is used for moulding imparts a grayish tint to the exterior of the brick. During the last three years the average annual output of this yard has been about three million brick. The brick sold in 1899 at an average of $4.25 per M. kiln run.

Laboratory Examination.—The Tramway clay was examined in the laboratory of the Survey and found to resemble very closely that used by the Wisconsin Red Pressed Brick Company at Menomonie. It is rather soft and crumbly when dry and smooth and moderately plastic when wet. The clay slacks very readily breaking down into a fine granular or scaly mass.

The red clay from the top of the bank consists of grains that have average diameters of about .012 mm. The largest grains observed were .057 mm. in diameter. Only a small percentage of the grains are under .003 mm. in diameter. Quartz is the predominant constitutent in this sample. Many of the grains are somewhat rounded in outline although some are angular and unequi-dimensional in size.

The bottom red clay is finer grained than the preceding, the largest individuals measuring about .04 mm. in diameter. The average grains are perhaps .0058 mm. in diameter. Many of the grains have angular outlines although some are fairly well rounded. Quartz is an abundant constitutent and the mass is well stained with iron oxide.

The blue clay contains many grains which are from .1 to .2 mm. in diameter. They have angular outlines and are unequi-dimensional in size. The grains will probably average about .014 mm. in diameter. About one-eighth of the mass consists of grains that are less than .0058 mm. in diameter. Quartz is an abundant constituent. The faint green color which the clay exhibits is thought to be largely due to chlorite.

WAUSAU.

Wausau is located in the central part of Marathon county on the Chicago & Northwestern and the Chicago, Milwaukee & St. Paul railroads. Five brick yards are located at this place which are owned respectively by Frank Doetschal, F. W. Garske, August Goebel, Henry Goebel, and Henry Rehlitz.

F. W. Garske's plant is located about two miles northwest of the city. One of the banks from which the clay is obtained has a thickness of three to three and a half feet. The color of the clay is reddish brown and is mixed with decomposed granite. The other clay bank has a depth of three feet and consists of one foot of heavy black clay and two feet of blue clay. The best brick are made by mixing the clays and weathering them over winter on the yard. The clay is mixed in a pug mill operated by horse power. The brick are made by hand, dried on pallets under sheds, and burned in a permanent up draft kiln.

This yard was opened in 1874, and has been operated each year since that time. The average annual output during the last three years has been about 250,000. The average price of the brick in 1899 was $7.00 per M. kiln run.

The yard owned by **Frank Doetschal** is located about three and one-half miles northwest of Wausau on the Merrill road. The bank from which the clay is taken has a thickness of five to six feet, consisting of one foot of black tough clay and four to five feet of blue clay variegated with streaks of yellow. The clay is soaked in a vat over night and mixed in wooden pug mills. The brick are moulded by hand, dried on pallets under sheds, and burned in a permanent up draft kiln. This yard was opened in 1899 and during that year about 35,000 brick were made. The brick sold for $7.00 per M. kiln run at the yard.

The yard owned by **August Goebel** is about two and one-half miles northwest of Wausau. The clay bank has a thickness of from two to four feet and the clay is essentially the same as that occurring at the previously described yards. The clay bank has a thickness of from two to four feet and the clay is essentially the same as that occurring at the previously described yards. The clay is soaked in a vat over night and afterwards mixed in a wooden pug mill operated by horse power. The brick are moulded by hand, dried on pallets under sheds, and burned in permanent up draft kilns.

This yard was opened in 1895 and has been operated each year since that time. The output during the last three years has averaged about 250,000. The brick sold in 1899 at the yard for about $5.50 per M. kiln run.

The brick plant owned by **Henry Goebel** is not far from that operated by August Goebel. The clay bank has a thickness of from two to three feet and is very similar to that which occurs at the previously described yards. The clay is soaked from one to three days in a vat and then mixed in pug mills operated by horse power. The brick are moulded by hand, dried on pallets under sheds, and burned in permanent up draft kilns. This yard was opened in 1893 and has been operated each year since that time. The average annual output of the yard during the last three years has been about 200,000.

The yard owned by **Henry Rehlitz** is located a little southeast of the city. The clay bank consists of a stripping of soil and sod at the top, four feet of yellowish blue clay, and three feet of blue clay stained with yellow spots. The clay is soaked in vats over night and afterward mixed in a pug mill. The brick are moulded by hand, dried on pallets under sheds, and burned in permanent up draft kilns. The output of this yard in 1899 was 300,000. The brick sold in 1899 for $6.50 per M. kiln run.

All of the clay which occurs at the different Wausau brick yards is essentially the same. It differs mainly in the percentage of loam and sand. The brick are manufactured in practically the same way. They are made by hand, dried on pallets under sheds, and burned in permanent kilns. The pallets which are used are frequently single boards without cleats. Such pallets have a tendency to warp and in drying the brick are distorted thereby.

WITHEE.

Withee is located in the north central part of Clark county on the Wisconsin Central railroad. The only brick yard at this place is situated about one mile east of the village and is owned and operated by **P. K. Peterson.** It was opened in 1893 and has been operated each year since that time. The clay bank has a thickness of about two feet. The clay has a yellowish blue color and contains occasional small granite pebbles. Underneath the yellow clay there is a considerable depth of blue clay which can not be worked on account of the quantity of gravel and boulders which it contains. The clay is soaked in a vat for half a day and then mixed with a tempering wheel. The brick are moulded by hand, dried in hacks on the yard, and burned in scove kilns.

The average output of this yard during the last three years has been about 80,000. The brick sold in 1899 for about $5.00 per M. kiln run.

WHITTLESEY.

Whittlesey is located in the northeastern part of Taylor county on the Wisconsin Central railroad. The plant which is located at this place is owned and operated by the

Langenberg Brick Company of which *George Langenberg* is superintendent. The clay bank has a thickness of from ten to twelve feet. The clay occurs in thin layers having a reddish brown color and is practically uniform throughout the bank. The clay is very similar to that which is worked at Menomonie but appears to contain somewhat less sand. The company owns about forty acres of land which is practically covered with clay to a depth of twenty-five feet.

The clay is transferred from the bank to the plant on dump cars by means of a cable and winding drum. The brick are moulded in a Wellington soft mud machine, dried on pallets under sheds, and burned in permanent up draft kilns. It requires from nine to eleven days to burn the brick. The color of the brick when properly burned is red.

The yard was opened in 1898 and during that year 200,000 brick were manufactured. The brick sold in 1899 for $7.00 per M. kiln run, on board cars.

Laboratory Examination.—In the laboratory this clay was found to be comparatively soft when dry and moderately plastic when wet. It slacks quickly in water breaking down into a reddish brown scaly mass. Under the microscope the grains were observed to range in size from .1 to .001 mm. and less in diameter. The average size is perhaps about .003 mm. The large individuals are better rounded than the smaller ones.

Quartz is a very abundant constituent and iron oxide serves to color the entire mass a reddish brown. Numerous thin, translucent flakes which were observed in the clay were taken to be kaolin. Some feldspar was also observed.

The chemical composition of the clay both at the top and bottom of the bank is given in table I of the Appendix.

The analyses there recorded show that the clay is essentially the same at the top and bottom of the bank. A comparison with the analyses of clays from Menomonie and Marshfield shows that this clay is a trifle higher in aluminum and lower in the percentage of calcium, magnesium, potassium, and sodium. This is one of the best common clays that has come under my observation.

CHAPTER XI.

THE HUDSON RIVER SHALE.

This formation, which extends in a narrow belt through the eastern part of the state, limited above by the Niagara limestone and below by the Trenton, consists of a very calcareous shale interlaminated with occasional beds of limestone. Outcrops of this shale occur at intervals throughout the entire area from the southern boundary of the state to Green Bay. The shale weathers very rapidly and breaks down into a coarsely pulverulent mass which can easily be reduced sufficiently fine for the manufacture of brick.

This is practically the only shale of any consequence occurring among the Silurian rocks of Wisconsin. The only rocks that can be in any way compared with these are the shaly layers of the lower portion of the Potsdam sandstone and the decomposed beds of pre-Cambrian schists which occur along the border of the northern crystalline area.

To some people it is a matter of surprise that this formation is not used more largely in the manufacture of brick. Some even have gone so far as to prophesy that the shale of which this formation is largely composed would eventually be used for the manufacture of paving brick. However, the high percentage of calcium carbonate which it contains renders it altogether unsuitable for the latter purpose. For the manufacture of common brick it is quite satisfactory although the percentage of calcite and dolomite is somewhat higher than in the lacustrine clays of the eastern and southern parts of the state. It is important when using this shale that it should be weathered for at least one season before being used. It must also be ground in a dry pan before it is suitable for tempering.

In many localities the lacustrine clays are equally as valuable for the manufacture of common brick and have the advantage of not requiring to be weathered or ground before being used. The principal advantage in using this shale lies in the fact that it is free from limestone or other gravel and there is little or no danger of the brick or tile bursting from slacking of the limestone after the brick are burned.

At the present time only two brick yards are using this shale for the manufacture of brick. One of these is operated by **Frenzel Brothers** at Oakfield, and the other is owned and operated by the **Cook and Brown Lime Company** at Stockbridge.

OAKFIELD.

Oakfield is located in the south central part of Fond du Lac county on the Chicago & Northwestern railroad. The only plant in operation at this place is situated about one mile north of the village and is known as the **Frenzel Brick and Tile Yard.** This is one of two plants which are using the Hudson River shale for the manufacture of brick and tile. The shale in the upper part of the bank has a yellowish color while that below is blue. The blue clay is hard and resembles slate when fresh but upon exposure to the atmosphere it breaks down into an irregular granular mass. After the clay has been weathered it takes on a grayish color and shows occasional streaks of yellow iron oxide mainly along the jointing planes.

The clay is passed through a crusher and conveyed by means of an elevator to a vat where it is soaked. The brick and drain tile are made in an Adrian stiff mud machine equipped with a side cut-off. The brick are dried on pallets under sheds and in hacks on the yard and burned in permanent up draft kilns.

The brick have a white or cream color with the exception of such as are underburned. The plant is supplied with both water and steam power.

This yard was opened in 1895 and has been operated each year since that time. The average annual output of brick during the last three years has been about 250,000. In 1898, $500.00 worth of tile were sold.

Laboratory Examination.—The shale which occurs at this place was examined in the laboratory of the Survey. It slacks quite readily breaking down into thin concentric scales which are easily reduced to a powder when pressed between the fingers. The clay is hard when dry and soft and plastic when wet.

Under the microscope the clay was found to consist of grains of two sizes. The large grains vary from .1 to .01 mm. in diameter and the small ones from .01 mm. down. The large grains are rhombic in shape and have much the appearance of calcite or dolomite. The shale contains a small percentage of recognizable quartz and kaolin.

It is a noteworthy fact that the brick which are burned out of this clay are larger after burning than before. This is owing to the expansion which takes place as a result of the calcite being transformed into the oxide and from that into the hydroxide.

STOCKBRIDGE.

Stockbridge is located in the west central part of Calumet county near Lake Winnebago. **The Cook and Brown Lime Company** own and operate a brick and tile plant at this place and use the Hudson River shale. It has essentially the same characteristics here as it has at Oakfield. The clay is distinctly bedded and possesses several sets of joints which break the rock into various sized polygonal blocks. The following is the succession of beds as they occur at this place, beginning at the top:

6 to 8 ft. of yellowish clay, mixed with pebbles and limestone, all of which should be stripped.

10 ft. of shale. Does not stand much heat.

3 layers of limestone.

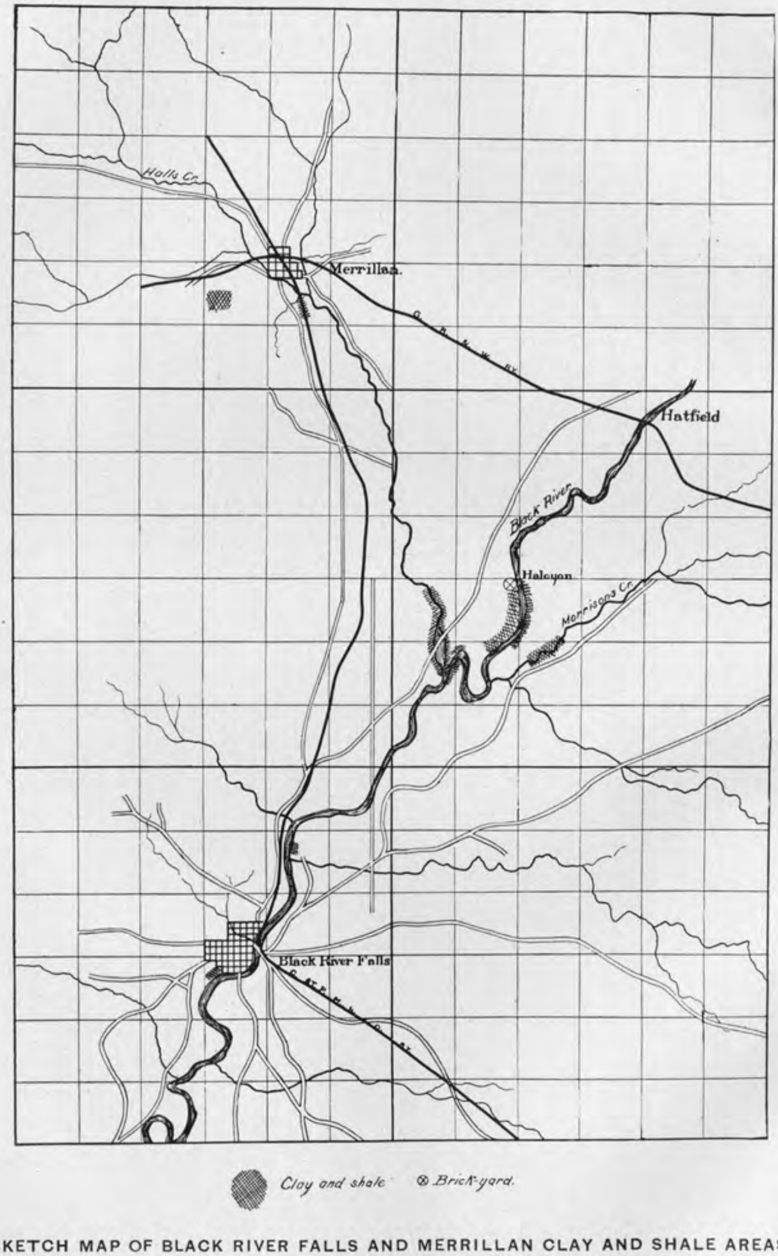
3 ft. of shale. Shrinks more than other shale beds and is used mainly in the manufacture of tile.

1 1-2 ft. of limestone.

15 ft. of shale. Shrinks very little in burning.

This plant is equipped with four machines, an Andrews Dry press, a Wellington soft mud machine, and two stiff mud brick and tile machines, an intermediate Wonder and a 9-A Brewer. The clay is weathered before using. For the manufacture of soft mud brick the shale is ground before being transferred to the machine. For the manufacture of tile the clay is ordinarily screened after being ground. The brick and tile are dried in a Wolff drier which has a capacity of about 30,000 per day. The tile are burned in a Eudaly down draft kiln and the brick are burned in permanent up draft kilns. About one-third of a cord of wood is consumed for each thousand brick burned.

The brick have a straw yellow color but owing to the sand used in moulding they are usually finely speckled. The brick do not melt around the arches and give evidence of standing a moderate heat.



SKETCH MAP OF BLACK RIVER FALLS AND MERRILLAN CLAY AND SHALE AREAS.

CHAPTER XII.

THE KAOLINIC SCHISTS OR SHALES OF THE PRE-CAMBRIAN ROCKS.

Whenever the rivers cut through the sandstone formation near its contact with the pre-Cambrian rocks the latter are frequently very much altered or decomposed to a depth of from ten to forty feet. Immediately at the contact, the schists which compose the pre-Cambrian rocks at many places are frequently almost completely kaolinized resulting in a clay which is nearly white. Deeper down the rocks are less and less altered until the hard, little decomposed rock is found. These shales, as they are called, usually contain a moderately high percentage of alumina and silica and are relatively low in calcium and magnesium. They can be mined comparatively easy as they occur in the bank but their value is materially increased by weathering for a season. When used the shales should be ground in a dry pan before they are tempered.

These shales are being employed for the manufacture of brick at four different places in this area. In two places soft mud brick are being made, at one plant stiff mud brick, and at the other dry press brick. The following descriptions of the individual plants, combined with the discussion on pages 31 and 32 will furnish the reader a fair idea of the general character and suitability of these clays for the manufacture of brick and other wares:

BLACK RIVER FALLS.

Black River Falls is located in the west central part of Jackson county on the Chicago, St. Paul, Minneapolis, and Omaha railroad. The only brick plant in this vicinity is situated about eight miles north of the city at a place called Halcyon. This plant, which is known as the **Halcyon Pressed Brick Yard,** is owned and operated by *H. A. Bright.* Mr. B. A. Bright is superintendent and manager and Mr. Perry is foreman at the plant.

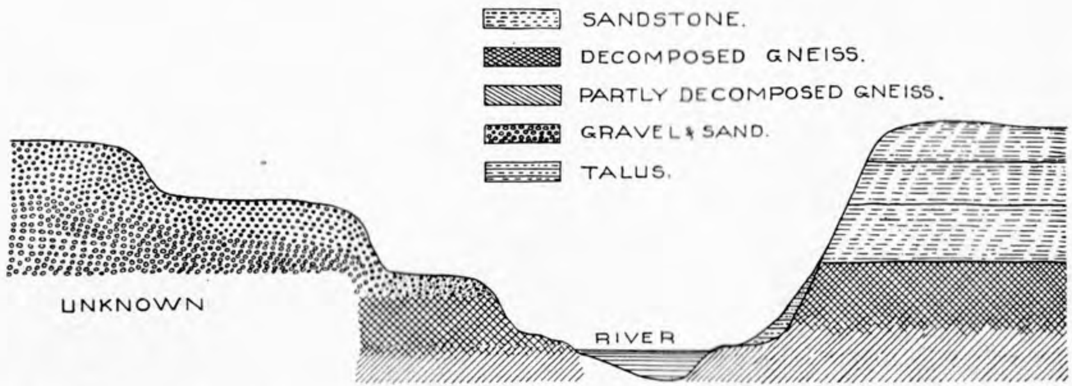
The brick are made from a very much decomposed schist of pre-Cambrian age which is widely distributed along the Black river and its tributaries known as Hall and Morrison Creeks. In places the shale is exposed continuously for a quarter of a mile or more along the bank adjacent to the river. Along one of the tributaries a thickness of from ten to twelve feet of shale above the river is exposed continuously for over half a mile. In most places the shale is covered with soft Potsdam sandstone, although frequently the sandstone is removed and the clay is either exposed at the surface or covered with various depths of sand and gravel.

In some places the shale is almost completely kaolinized and white. In other places the composition varies and with it the color, which is blue, green, or buff.

The accompanying map shows the location of the plant and the distribution of the clays in the immediate vicinity.

Where the shale is mined it is comparatively soft at the surface but the hardness increases with depth. The clay can be best worked after it has been weathered on the yard through one season. Up to the present time, however, it has been removed directly from the bank and dried for a short time under a shed, ground in a dry pan, and transferred to the press.

No attempt has been made to carefully separate the clay which burns white or buff from that which burns red, on account of which many of the brick have a pink color. The brick are in reality many different shades of red and pink



IDEAL SECTION ACROSS THE BLACK RIVER AT HALCYON SHOWING THE SHALE OR PARTLY DECOMPOSED GNEISS.

and great care and experience is required to properly shade them in sorting.

The shale occurs in layers which stand nearly on end in the bank. The layers form bands which often differ materially from one another in composition, although when taken separately they are comparatively uniform in composition. The clay from one of these bands may burn red, another buff, and a third white. The foreman of the bank should possess knowledge of the exact color to which the clay in each of these bands will burn. If this is known and the clay from the different bands is mixed in definite proportions there will be little difficulty in securing brick of almost any color without the necessity of such careful grading after the brick are burned.

In the manufacture of dry press brick these clays should be used sufficiently wet so that they will retain their sharp edges when removed from the moulds. The brick should be burned very slowly and when the heat has reached a point a little below vitrification it should be held for some time. The kiln should also be cooled slowly to give the brick time to anneal.

The brick which are now manufactured at this place are of excellent quality and sufficiently well graded to be suitable for the best kind of constructional work. The brick are burned in round down draft kilns. About eight days are required for burning, wood being used for fuel.

This plant was constructed in 1892 and has been operated each year since that time with the exception of 1894 and 1895. During the last three years the average annual output of the yard has been about 500,000 brick. The distance from the nearest railroad is the chief hindrance to the successful operation of the plant.

Miscellaneous Deposits of Clay and Shale.—About one mile and a half north of Black River Falls near the old iron furnace there are from ten to twenty feet of decomposed ferruginous schist which might be used to mix with the clay at Halcyon for the manufacture of dark red brick.

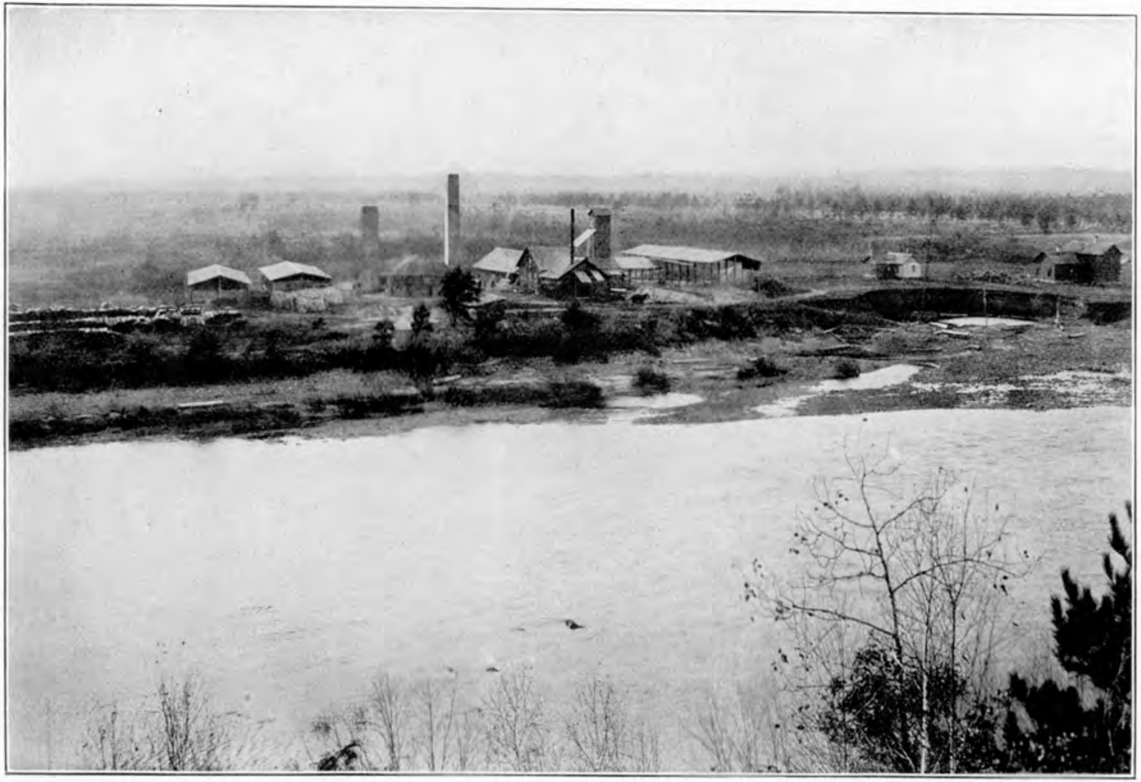
However, there is an abundance of clay nearer at hand which contains sufficient iron to color the brick any desired tint of red or brown.

About one-fourth of a mile south of the city is located an excellent bank of plastic blue clay which has a thickness of from six to thirty feet. The clay is overlain with from ten to thirty feet of sand and gravel which may prevent its economical development. The clay is finely laminated, very plastic, and apparently contains no gravel. Directly underneath the sand the clay has a yellowish gray color but three or four feet deeper down the color is uniformly blue. It is thought that the clay would make an excellent soft mud and perhaps stiff mud brick.

The clay at the top contains more quartz sand than that near the bottom. However, if the clay from the entire bank were used it is thought that the brick made therefrom would be very satisfactory. The location of the clay is such that the brick could be conveyed to the railroad for shipping without any unreasonable expense.

Laboratory Examination.—All of the clays from this region have been examined in the laboratory of the Survey. The shales from the Halcyon district break down slowly when soaked in water but are as a rule very plastic when wet. The greenish blue shale consists of grains which vary in size from .25 mm. to about .003 mm. in diameter. The individuals are irregular and angular in outline. Quartz, kaolin, feldspar, mica, and chlorite are the predominant constituents and are present in proportions which could not be determined with the microscope.

The white or yellowish white shale slacks very slowly. When pressed with the fingers it forms a very plastic sticky mass. Under the microscope it appears as a mass of many sized grains with sharp angular outlines. The individuals range in size from .2 mm. to .003 mm. and less in diameter. The greater part of the grains, however, are over .014 mm. in diameter. The grains have a sharp splintery appearance and are far from equi-dimensional in



THE HALCYON BRICK AND TILE WORKS, BLACK RIVER FALLS.
GENERAL VIEW OF THE WORKS SHOWING CLAY PIT AND FACTORY.

shape. Kaolin, quartz, iron oxide, and tremolite were observed. It is hardly possible to determine the proportions in which the different minerals are present.

The clay which occurs near the abandoned iron furnace shows a very high percentage of iron oxide under the microscope. The individuals were unequal in size and irregular in shape. Most of the grains are .014 mm. or over in size. The clay consists mainly of quartz, kaolin, mica, hornblende, and iron oxide.

The blue clay which occurs below the city slacks very readily in water breaking down into fine scales. When wet it is moderately plastic. Under the microscope it is found to consist of a heterogeneous mass of grains ranging in size from .067 to .001 mm. in diameter. The individuals are very generally rounded and cluster together under the field of the microscope. They all have a dirty, greenish brown color. The clay contains a considerable percentage of quartz in grains of moderate size, iron oxide, and other mineral constituents which were obscured by the brown staining.

The clay from Hall's Creek, which is not far from the Halcyon Brick plant, was found when examined under the microscope to consist of grains which vary in size from .1 to .001 mm. in diameter. The individuals have sharp, splintery, and in some cases almost crystal outlines. The individuals have a greenish tint although remarkably clear and translucent. Quartz, chlorite, kaolin and other undeterminable minerals are present in varying proportions.

The clay breaks down slowly in water and will require grinding before it is sufficiently fine for the manufacture of brick. The clays are all fairly plastic although not as much so as the samples examined from the Halcyon plant. They have a grayish blue color and will undoubtedly burn red.

The following are the chemical analyses of samples from this region: Nos. 117, 118, 119, 120, 121 are from the shales now being used at the Halcyon Brick Plant. Nos.

11 and 12 are from Hall's Creek, and No. 13 is the plastic clay from the river below Black River Falls.

	No. 117.	No. 118.	No. 119.	No. 120.
H_2O,C	5.26	3.68	6.22	4.38
SiO_2	70.30	72.30	55.87	65.52
Al_2O_3	18.07	16.06	19.60	16.33
Fe_2O_3	1.65	.35	9.22	4.02
CaO	....	.26	1.05	1.65
MgO	.90	1.50	3.71	3.09
Na_2O	.76	.40	.32	.33
K_2O	2.94	5.23	3.93	3.94
P_2O	.06	trace.	.06	.58
Total	99.94	99.78	99.98	99.94

	No. 121.	No; 11.	No. 12.	No. 13.
H_2O, C	3.86	4.40	7.16	9.10
SiO_2	67.96	59.88	50.17	61.22
Al_2O_3	17.25	18.10	17.90	13.98
Fe_2O_3	2.27	10.04	12.29	4.66
CaO	.67	.31	0.55	3.76
MgO	2.07	3.13	6.86	2.03
Na_2O	.38	.52	0.58	1.32
K_2O	5.81	3.72	3.06	3.44
P_2O	trace.	....	....	....
MnO	....	trace.	0.61	....
TiO_2	....	....	0.75	0.43
Total	100.27	100.10	99.93	99.94

GRAND RAPIDS.

Grand Rapids is located in the central part of Wood County on the Wisconsin River. Two brick plants have been erected near this place. One is owned by **Lessic and Sons** and the other by **Scott and Alexander.**

The plant owned by Scott and Alexander, known as the *Grand Rapids Pressed Brick Yard,* is located at Sigel Station about three miles northwest of the city. This yard

HALCYON BRICK AND TILE WORKS, BLACK RIVER FALLS.

NEAR VIEW SHOWING KILNS AND SHEDS.

was opened in 1897 and has been operated each year since that time. The average output during the last two years has been about 1,700,000 common brick per year.

The clay occurs in a low, swampy tract of land near the railroad. The bank consists of from one to two feet of sand at the top, three to four feet of blue clay much discolored with yellowish brown streaks of iron oxide, and about six feet of decomposed granite schist. The best brick are said to be manufactured out of a mixture of the clay from the upper and lower parts of the bank. The clay is conveyed from the bank to the plant in dump cars operated by a cable and revolving drum. The clay is mixed and tempered by passing through two pug mills. The brick are made in a Monarch soft mud machine, dried on pallets under sheds, and burned in permanent up draft kilns. The capacity of the dry sheds is 225,000 and that of the kilns one million. The clay burns red and it is reported that the brick will withstand a high heat.

The transportation facilities are not good and for this reason the company have been working under a disadvantage in placing their product on the market at a price which can compete with other factories.

In the vicinity of Grand Rapids there are extensive areas of residual clay formed out of decomposed granite gneiss, some of which is almost pure white and carries a high percentage of plastic kaolin. The clay, however, is usually stained with a greater or less percentage of iron oxide on account of which it is unsuitable for the manufacture of white ware. The purest of the clays might, when mixed with silica in proper proportions, make a fire brick which would be suitable for many purposes.

Mr. Alexander is contemplating moving the brick yard in which he is interested to a place where the white clay occurs and there begin the manufacture of refractory brick. The establishment of such an industry at this place would provide manufacturers with a product which is at present only obtained outside of the state. Brick manufactured out of this clay will undoubtedly be sufficiently refractory for many purposes for which fire brick are now used.

Laboratory Examination.—Three samples of clay from unworked banks in this vicinity were examined in the Survey laboratory. Two of the samples were very ferruginous and the third was almost free from iron. The ferruginous samples were hard and slaty when dry and broke down very slowly in water. When ground and soaked with water the color of both was a deep brown. The mass was only moderately plastic.

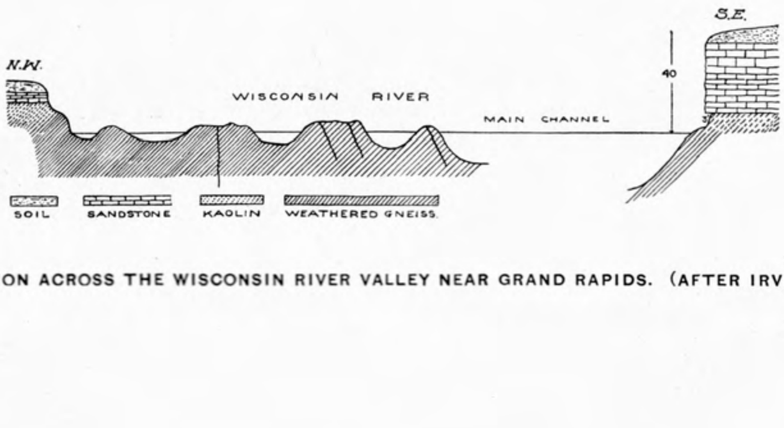
The microscopic examination shows that these samples consist of quartz, kaolin, mica, iron oxide, and chlorite with possibly some tremolite.

The grains differ greatly in size depending upon the grinding to which they have been subjected. They are irregular in outline and have a splintery appearance.

The third sample which had a grayish white color was streaked with a faint coloring of yellow iron oxide. The clay has a puckery taste which is due to the presence of soluble iron and aluminum sulphate. The clay slacks readily in water and is very plastic when wet.

Under the microscope the grains were observed to have very irregular, splintery outlines. They differ greatly in size but none are what might be called coarse.

The clay consists mainly of quartz, kaolin, a small amount of iron, and probably some feldspar. The following are the chemical analyses of the three clays above described. Nos. I and II are the brown samples of shale and No. III is the white clay or kaolin.



SECTION ACROSS THE WISCONSIN RIVER VALLEY NEAR GRAND RAPIDS. (AFTER IRVING.)

	No. I.	No. II.	No. III.
H_2O, C_1	4.69	9.10	6.47
SiO_2	52.52	34.44	67.50
Al_2O_3	14.65	17.26	0.25—Soluble.
Al_2O_3	....	....	19.23—Insoluble.
Fe_2O_3	18.07	23.80	0.06—Soluble.
Fe_2O_3	....	....	2.60—Insoluble.
CaO	0.94	0.27	....
MgO	2.40	11.21	.83
Na_2O	0.34	0.22	0.48
K_2O	5.52	1.94	2.50
TiO_2	1.35	0.47	....
MnO	trace.	1.55	....
SO_3	....	....	0.26
Total	100.48	100.26	100.18

The deposits of clay in the vicinity of Grand Rapids have been discussed somewhat at length by R. D. Irving in the third volume of the "Transactions of the Wisconsin Academy of Sciences, Arts, and Letters." The relation of these kaolin deposits to the underlying granite gneiss and the superimposed sandstone is nicely shown in the accompanying diagram which has been taken from this paper. The gneisses in this region have a well defined lamination or schistosity which strikes between N. 45° E. and N. 80° E. and dips about 50° either east or west. The beds of Potsdam sandstone which are above the kaolin are horizontal as shown in the accompanying illustration.

The following analyses, made by E. T. Sweet and published as a part of the report of R. D. Irving in the Academy Transactions above referred to, represent very truthfully the character of the residual kaolins of this region. In all of the samples there is a relatively high percentage of quartz and moderate amounts of sodium and potassium. The presence of from two to three and a half per cent of fluxes lessens very materially the refractory character of the clays.

*Analyses.**

Location.	Silica.	Alumina.	Iron.	Calcium.	Magnesium.	Potassium.	Sodium.	Water.	Titanium.	Carbon dioxide.	Total.
Grand Rapids (unwashed)........	78.83	13.43	0.74	0.64	0.07	0.37	0.07	5.45	....	0.01	99.60
Grand Rapids washed)........	49.94	36.80	.72	t'ce	....	0.51	0.08	11.62	....	....	99.67
Lot 5, Sec. 24, T. 22 R. 5 E..........	70.83	18/98	1.24	0.24	0.02	2.49	0.10	5.45	....	0.02	99.37
Near the above clay............	70.25	17.68	2.32	0.33	1.49	1.69	0.39	5.61	....	t'ce	99.76
Near the above clay............	69.34	19.19	1.75	0.44	0.31	3.30	2.43	2.67	....	....	99.43
Sec. 22, T. 26, R. 5 E...............	54.87	28.87	1.54	1.62	0.99	2.57	0.07	9.48	0.95	....	100.56

STEVENS POINT.

Stevens Point is located near the central part of Portage county on the Wisconsin river. The only brick yard at this place, which is owned and operated by the **Langenberg Brick Manufacturing Company**, is located one and one-half miles north of the city. The bank from which the clay is obtained consists of about three feet of surface clay, which appears to have been modified more or less by water, and an indefinite thickness of decomposed schist, which is, in some places, so thoroughly disintegrated that it appears much like clay. Parts of the bank are thoroughly decomposed but other portions contain large semi-decomposed blocks of granite gneiss which are still too hard to work without grinding. The bank is traversed by occasional dark brown streaks which consist almost entirely of black mica. In one place the bank is intercepted by a band of red clay which has much the appearance of a decomposed greenstone dike. I believe, however, that the band is sim-

*Transactions of the Wisconsin Academy of Sciences, Arts, and Letters, Vol. III, p. 29.

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THE GRAND RAPIDS PRESSED BRICK CO., GRAND RAPIDS.

FIGURE 1.—GENERAL VIEW OF THE YARD AND WORKS. FIGURE 2.—THE EMPLOYEES.

ply an accumulation of clay from the surface which has filled what was formerly a wide crevice in the rock. Numerous veins of white quartz are exposed in the bank. Due to weathering, these veins, which are in reality sheets of quartz, have been much broken up.

The clay of the more decomposed portions of the bank has a bluish color, while the schist underneath varies in color from green and blue to yellow and red. The clay contains a considerable portion of kaolin mixed with feldspar, quartz, and mica.

The brick which are manufactured from this clay are various shades of red, depending upon the portion of the bank from which the clay is obtained.

The clay is conveyed to the works on dump cars operated by a cable and winding drum. The clay is passed through a pulverizer and two sets of crushers. From the crushers the clay goes directly into a pug mill, where it is mixed and tempered. The brick are made in a Sword machine, dried in hacks on the yard, and burned in permanent up draft kilns.

After passing through the pulverizer and crushers the clay still contains quartz gravel which causes the brick to crack in drying. This cracking is due to the differential shrinkage between the clay and the gravel. To work this clay properly it should be ground in a dry pan first and then screened, in order to remove or pulverize all coarse particles such as now occur in the clay.

The capacity of the dry yard is 350,000 and that of the kilns 1,400,000. It requires seven days to burn the brick and about one half of a cord of wood is consumed for each thousand brick burned.

RINGLE.

Ringle is located in the east central part of Marathon County on the Chicago and Northwestern Railroad. The only brick plant at this place is owned by *John Ringle* of Wausau, and is known as **The Clay Lumber Company's brick yard.**

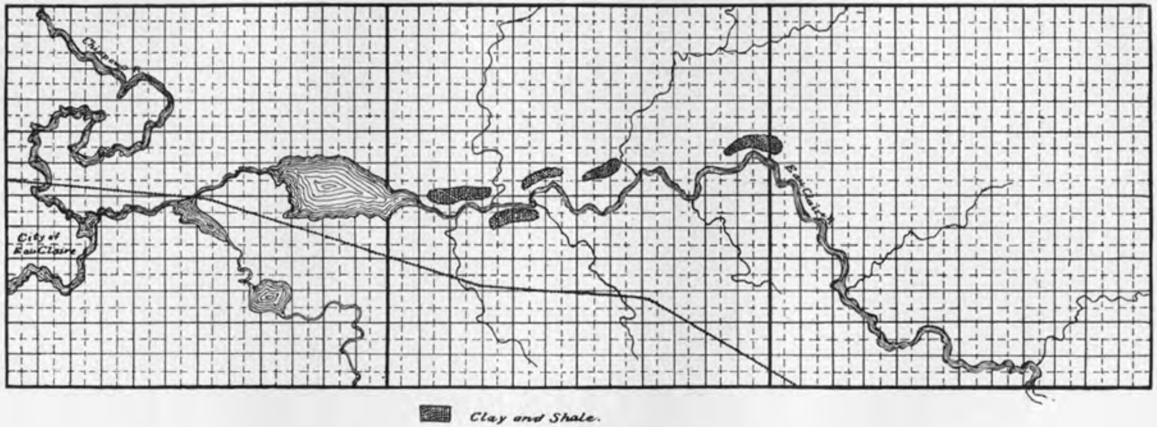
The bank from which the clay is obtained consists of a varying thickness of decomposed granite gneiss covered with a maximum thickness of three feet of sand and gravel. Underneath the gravel and sand occurs a dark red, plastic clay which is from one to three feet in thickness; three to four feet of dark blue clay; and an undetermined depth of dark blue, partly decomposed gneiss. The clay which occurs directly above the partly decomposed gneiss works easiest and best under the present arrangement.

The clay is conveyed from the bank to the brick plant on cars run by a cable and winding drum. It is passed through a crusher and mixed in two Potts pug mills. The brick are made in an A. & C. Potts soft mud machine, dried on pallets under sheds, and burned in permanent up draft kilns. A Raymond hand re-press is used for making select or veneer brick.

This yard was opened in 1893 and has been operated each year since that time. The average annual output during the last three years has been about 1,000,000 brick. The brick show the effect of the quartz gravel which works through the crusher and is moulded with the clay into the brick. The only way to successfully remove this gravel is to use a dry pan and screen. The use of this additional machinery will make the working of the clay more expensive but the brick will be better. As now manufactured the brick have an excellent red color and are strong. The main objection to them is the sometimes rough faces which are undesirable for front or veneer work.

Laboratory Examination.—Three samples of clay from this place were examined in the Survey laboratory. The sample which has a chocolate brown color slacks quite readily in water and is very plastic when wet. The other samples which have a bluish or grayish green color slack very slowly and are much less plastic.

The first mentioned sample consists of grains which are mainly less than .0058 mm. in diameter. The individuals are angular in outline, although more regular than those



THE KAOLINIC SCHIST OR SHALE AREAS OF THE EAU CLAIRE RIVER DISTRICT.

in the other two samples. The minerals are deeply stained with iron oxide and their identity is somewhat uncertain. Quartz, mica, kaolin, and iron oxide are thought to be the main constituents.

The other two samples were very much alike, the only appreciable difference being in the percentage of iron oxide present. The grains were all very regular and ranged in size from .1 mm. down to .001 mm. and less in diameter. The large grains appear to be scattered promiscuously in a mass of very small flakes and splinters. The grains have a general greenish tint and are more or less stained with iron oxide.

The largest part of these samples appear to be quartz, although feldspar, kaolin, chlorite, and iron oxide occur in unknown proportions.

The chemical composition of these clays is given in the following analyses. No. I is the chocolate brown clay and Nos. II and III are the blue or greenish gray clays, representing the less decomposed gneiss.

	No. I.	No. II.	No. III.
H_2O, C	6.86	6.00	6.14
SiO_2	52.60	54.47	49.92
Al_2O_3	14.42	13.68	13.03
Fe_2O_3	16.00	15.96	20.20
CaO	0.65	0.55	0.31
MgO	3.15	3.17	4.15
Na_2O	0.36	0.40	0.40
K_2O	4.90	4.60	5.72
TiO_2	0.80	1.10	0.85
MnO	0.47	0.33	0.21
Total	100.21	100.26	100.30

The clays from this vicinity could be used successfully for the manufacture of both stiff mud and dry press brick if selected properly from the bank and worked in a thorough manner.

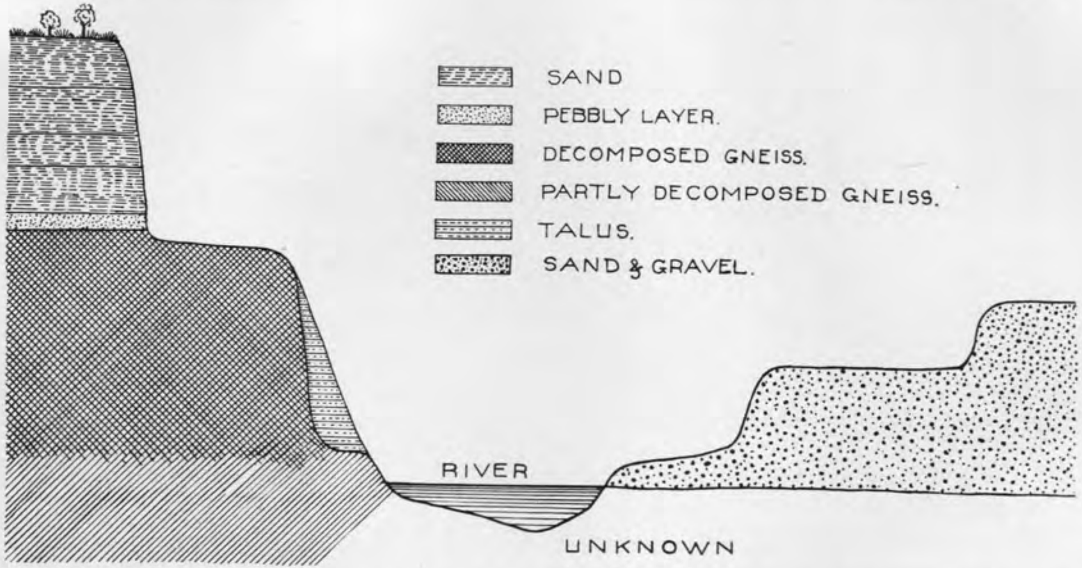
EAU CLAIRE.

One of the very promising undeveloped areas of pre-Cambrian shale occurs immediately east of the city of Eau Claire and along the Eau Claire river. The shales which occur in great quantities in this area are similar to those near Black River Falls, now being used by the Halcyon Brick Company. They are very much decomposed gneisses of the pre-Cambrian formation. They extend along the river at intervals for a distance of about ten or twelve miles and are easily accessible at many places. The workable portions of the beds attain a maximum thickness above the level of the river of about thirty-five or forty feet, although in some places they are at or below the river level. They are, however, sufficiently extensive to warrant the assertion that the supply is practically inexhaustible.

The shales occur directly beneath the Potsdam sandstone, or where the sandstone has been eroded away they occur underneath various thicknesses of river gravel. Wherever it has been possible to obtain evidence, it is apparent that the shales gradually pass downward into less and less altered rock until the hard compact gneiss is reached. The shales have a laminated structure, often mistaken for bedding, which has an almost vertical dip and a strike which is in some places N. 75 W. The shales are also traversed by numerous jointing planes, striking in various directions.

Near the contact with the sandstone, or at the surface, the shale is very soft, having most of the characteristics of clay. Deeper down it becomes harder but for a depth of two to fifteen, and sometimes thirty feet, it is sufficiently soft, so that it can be handled with pick and shovel. Wherever it has remained exposed to the atmosphere for a short time, it crumbles into a fine pulverulent or scaly mass.

The shales differ very greatly in color in different parts of the exposures. Near the contact with the sandstone they are often white or but slightly streaked with iron oxide. A



IDEAL SECTION ACROSS THE EAU CLAIRE RIVER VALLEY SHOWING THE SHALE OR DECOMPOSED GNEISS.

foot or two below the sandstone the shale may be purple, brown, green, blue or gray. Sometimes one may find broad bands of blue or greenish colored shale, alternating with bands of purple or reddish brown. The bands of light colored, almost white clay, are in some places quite extensive.

The shale differs in composition in different parts of the formation. It contains kaolin, quartz, mica, chlorite, iron oxide, feldspar, and other minerals in lesser proportions. These minerals occur in individuals that vary greatly in size, ranging from one-fifth to one-thousandth of a mm. in their greatest diameter. The outlines of the individuals are irregular and angular.

The chemical composition of these shales will be found in Table I of the Appendix. The samples analyzed and tested were furnished by George T. Thompson of Eau Claire who expects to establish a brick factory at this place.

CHAPTER XIII.

KAOLIN.

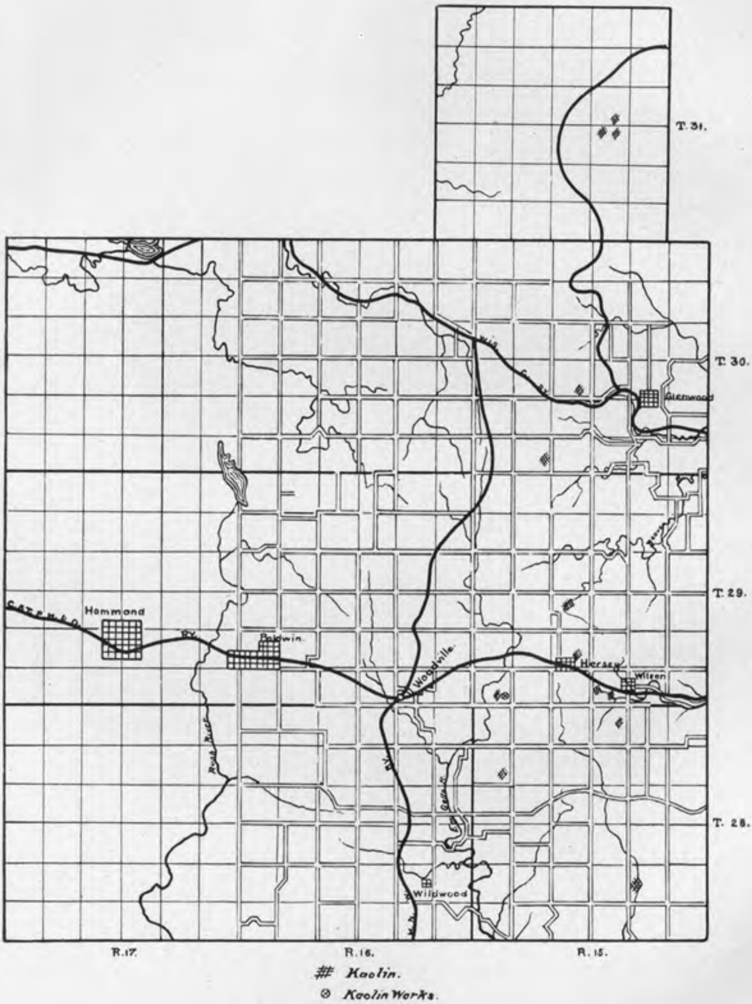
The kaolin deposits within the state occur in two very different forms. The most widely distributed deposits are the impure residual clays which are associated with the pre-Cambrian schists, near the contact of these rocks with the sandstone of the Potsdam formation. These deposits occur in the vicinity of Grand Rapids, Eau Claire, Black River Falls, Rice Lake, Stevens Point, and other places. As a rule the deposits contain considerable amounts of quartz and iron oxide but occasionally they are sufficiently free from these constituents so that kaolin can be obtained by washing, which would be suitable for the manufacture of white ware.

These deposits have been considered in detail in the previous pages, with the exception of that which occurs near Rice Lake and Eau Claire.

Non-plastic Kaolin.

RICE LAKE.

The Rice Lake kaolin is found in the N. W. ¼ of S. E. ¼ of Section 19, Town 35, Range 9 West, on property owned by Mr. Mallo. It occurs under a covering of about thirty feet of yellow clay and fragments of brown ferruginous rock. The kaolin bed is reported to have a thickness of seven feet. When the property was inspected in 1899 the



A PORTION OF ST. CROIX COUNTY SHOWING LOCATION OF A FEW OF THE KNOWN DEPOSITS OF PLASTIC KAOLIN.

shafts which had been sunk were not in a condition so that the deposit could be examined.

Samples of the kaolin which were sent to the Survey were found to be practically devoid of plasticity. They were hard and yet somewhat crumbly. The samples were intercepted with numerous fine seams, the walls of which were stained with iron oxide.

A chemical analysis of this kaolin showed it to be high in aluminum. Its lack of plasticity, however, renders it altogether unsuitable for the manufacture of porcelain ware when used alone.

This kaolin is thought to belong to a later formation than the schists which occur at Eau Claire and other places. However, its age has not been definitely determined. An analysis of this kaolin is given in table I of the Appendix.

Plastic Kaolin.

The second and best known form in which the kaolin occurs is a very plastic sedimentary deposit interstratified with sand. These deposits are younger than the Rice Lake kaolin but are thought to be at least pre-glacial in age. These kaolins occur mainly in the eastern part of St. Croix County and the western part of Dunn County. A few of the many places where the kaolin may be observed at or near the surface of the ground are shown in the accompanying sketch map.

GLENWOOD.

In the vicinity of Glenwood the kaolin deposits have been quite thoroughly explored by H. J. Baldwin. It has never been my good fortune to have an opportunity to examine carefully the kaolin as it occurs in this vicinity, although I have made borings at several places, all of which show a variable thickness of kaolin. The beds are everywhere covered with boulder clay to a depth of from five to fifteen feet.

Samples from this region show a very excellent grade of clay. It is remarkably free from iron in some places, but again it may be deeply stained with limonite. The chemical composition of this clay is given in table I of the Appendix.

HERSEY.

Hersey is located in the southeastern part of St. Croix County on the Chicago, St. Paul, Minneapolis and Omaha Railroad. About two miles southwest of the village is located the plant of the **Superior China Clay Company**, which is engaged in mining and washing white plastic kaolin. The plant, which is one of the largest of its kind in the United States, was erected in 1893 and has been operated each year since. The washing plant is located immediately at the mines and both are operated about seven months during the year, it being impracticable to operate the plant during the severe winter weather of this latitude.

Deposits of kaolin occur in irregular beds and pockets in many places in the western part of Dunn County and in the eastern part of St. Croix County. In some places it is found near the surface and in others it is covered to a depth of thirty feet or more with boulder clay. The kaolin in some of the beds is pure white, while in other places it is deeply stained with yellow iron oxide.

Very little of the clay that is mined by the Superior China Clay Company is stained with iron. That which is stained is carefully sorted and kept apart from the white. Among these deposits the clay which occurs at the greatest depth is the purest. The kaolin which is near the surface occurs in lumps of boulder form and contains upwards of fifty per cent of free silica, while at a depth of about eight feet the kaolin occurs in parallel sheets or strata varying in thickness from a few inches to two feet or more. The sheets of clay are separated from one another by layers of white sand from a few inches to several feet in thickness. The beds near the surface seldom continue in uninterrupted sheets, but are usually folded and broken in such

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SUPERIOR CHINA CLAY WORKS, HERSEY.

PITS FROM WHICH KAOLIN IS MINED.

a manner as to lead one to suspect that they have been subjected to pressure. It is supposed that these deposits were formed prior to the last glacial epoch and that the advance of the ice has crumpled and folded the beds.

The clay is loosened from the bank by the use of picks and shovels and carefully sorted by hand, all clay showing iron stains being thrown aside. It is placed in iron buckets, raised out of the pits by means of derricks, and loaded into dump carts in which it is conveyed to the washing plant. At the washing plant it is dumped onto a platform and shoveled into a pug mill, where it is mixed with copious amounts of water and thoroughly disintegrated. From the first pug mill the clay passes into a second pug mill in which any remaining lumps of clay are reduced to a powder. The thin slip which is thus formed out of the clay and water is conducted into long troughs through which it slowly flows for a distance of from 7,000 to 8,000 feet. These troughs are slightly inclined, the speed of the water being decreased as the outlet is approached. At the end of these precipitating troughs the clay passes through a very fine screen by means of which all foreign material is removed. The slip is then run into a series of large settling vats, the aggregate capacity of which is over 2,500,000 gallons.

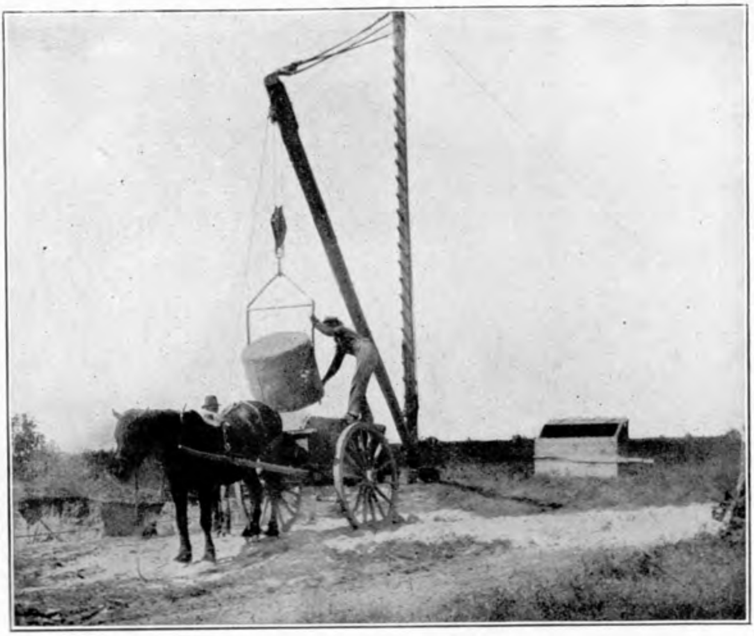
As the clay passes into the precipitating troughs it contains a considerable quantity of white sand of all degrees of fineness which, owing to its greater specific gravity, is deposited in the bottom of the troughs as the slip slowly moves toward the settling vats. When the clay has settled to the consistency of thick cream it is drawn off into an underground tank from which it is pumped into filter presses where it is subjected to an hydraulic pressure of from ninety to one hundred pounds. On account of the fineness of the clay and its great plasticity the process of pressing the water out of it is very slow, it taking from six to eight hours to fill a filter press. The clay comes from the filter presses in cakes or discs which weigh about twenty-five pounds and are loaded onto dryer cars which are run into a large steam tunnel dryer where the clay is subjected to a steam heat of about 220 degrees F. for about sixty hours. When the clay has been thoroughly dried it is taken from the dryer tunnels and crushed and packed in bags ready for shipment. The company has a warehouse capacity sufficient to store about 5,000 tons of clay. The plant has a capacity of from thirty-five to forty tons of washed clay per day and an annual capacity of from 4,500 to 5,000 tons.

During the process of washing the clay enormous quantities of almost pure white sand is removed and thrown into the yard from the precipitating troughs. This white sand is exceptionally pure and might be used in the manufacture of glass or pottery. It is far better than most of the sand that is now being used for filtering purposes.

The kaolin which is placed on the market by this company is equal in quality to any of the eastern or southern products which have come under my observation. The clay has been analyzed both in the crude and washed conditions. The following analyses show the condition of the clay as it was being mined in 1899. Sample I is the crude kaolin, and sample II is the washed product.

	Sample I.	Sample II.
H_2O	8.90	11.89
SiO_2	64.50	52.41
Al_2O_3	26.20	34.10
Fe_2O_3	.07	.15
CaO	....	.05
MgO	....	.12
Na_2O	....	.18
K_2O	.31	.46
TiO_2	....	.80
Total	99.98	100.16

Reference to the above chemical analyses shows that the percentage of iron is very low, being less than .07 in the sample of crude kaolin and less than .15 in the sample of



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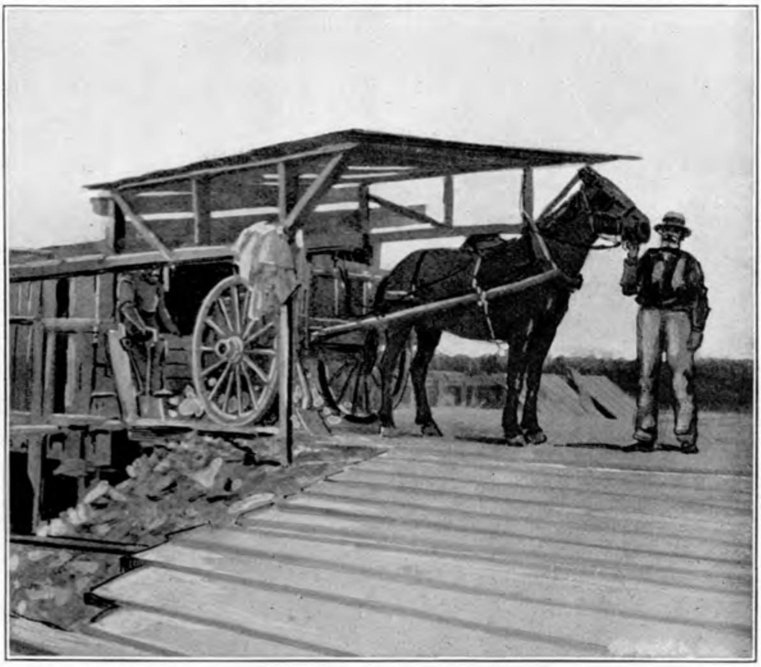

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SUPERIOR CHINA CLAY WORKS, HERSEY.

1. LOADING A CART FROM A PIT. 2. DELIVERING CLAY AT THE WASHING PLANT.

washed kaolin. The complex chemical composition of the washed kaolin may be partly due to the mineral constituents carried in the water used for washing the clay. The calcium, magnesium, sodium, and potassium may all have been derived from the water, although it is quite possible that certain parts of the clay may contain a small percentage of feldspar which would easily account for the presence of these elements.

Further examination of the crude clay in the laboratory shows that it slacks very readily in water, breaking down into a very plastic mass resembling slacked lime. Under the microscope the crude kaolin was observed to consist mainly of kaolinite grains, although numerous small grains of quartz were observed. The largest grains of kaolin were not over .0025 mm. in diameter. In the washed samples of kaolin very little quartz could be detected with the compound microscope. Such quartz grains as were observed were very minute. This would indicate that the separation in the washing process had been very thorough.

The output of the plant has been largely consumed by the paper manufacturers of Wisconsin and Minnesota. It has been tested a number of times for the manufacture of porcelain and the reports made indicate that it is well adapted for this purpose. From my examination I believe that the clay is well adapted for the manufacture of porcelain and sooner or later it will undoubtedly be used quite extensively for this purpose.

EAU CLAIRE.

Besides the kaolinic schists that occur in this vicinity there is also a limited area in the valley of the Eau Claire river in which considerable quantities of fine plastic kaolin occurs. This kaolin is mixed with considerable fine quartz and is interstratified with beds of sand.

A proposition was at one time entered into by which this kaolin was to be utilized as a polishing powder. This plan, however, never materialized and the kaolin remains as it was, practically untouched.

These beds occur in the present valley of the Eau Claire river and are thought to have been derived originally from the kaolinic schists which in some places constitute the bed of the river.

When the schists occurring in this region are developed it is very probable that this partly washed kaolin will be utilized.

SUPERIOR CHINA CLAY WORKS, HERSEY.

SECTION OF 8000 FEET OF PRECIPITATING TROUGHS.

CHAPTER XIV.

SHALES OF THE POTSDAM FORMATION.

The base of the Potsdam formation in many places consists of alternating layers of tough plastic clay and sandstone. In some places the clay has been distributed through the body of the stone in such a manner as to form a brown shale which has a maximum thickness of from seven to ten feet. In most places, however, the clay layers are not over an inch in thickness. Occasionally they measure from twelve to eighteen inches.

At the present time these clays and shales are nowhere being used for the manufacture of brick or other clay wares. The only use to which the shale is being put is the construction of highways. The mixture of tough clays and moderately hard sandstone makes a roadway which is far superior to an ordinary clay or sand road.

This shale or clay occurs at many places, chief among which are Merrillan, Durand, Black River Falls, Eau Claire, Neillsville, and Fond du Lac in Douglas County.

MERRILLAN.

Merrillan is located in the north central part of Jackson County at the junction of the Chicago, St. Paul, Minneapolis and Omaha and Green Bay and Western Railroads. Almost the entire region in the vicinity of this city is underlain with clay which has a thickness of three to eight feet. The clay has either a bluish green or reddish brown color and occurs either as an alluvial deposit or interlaminated with thin layers of Potsdam sandstone.

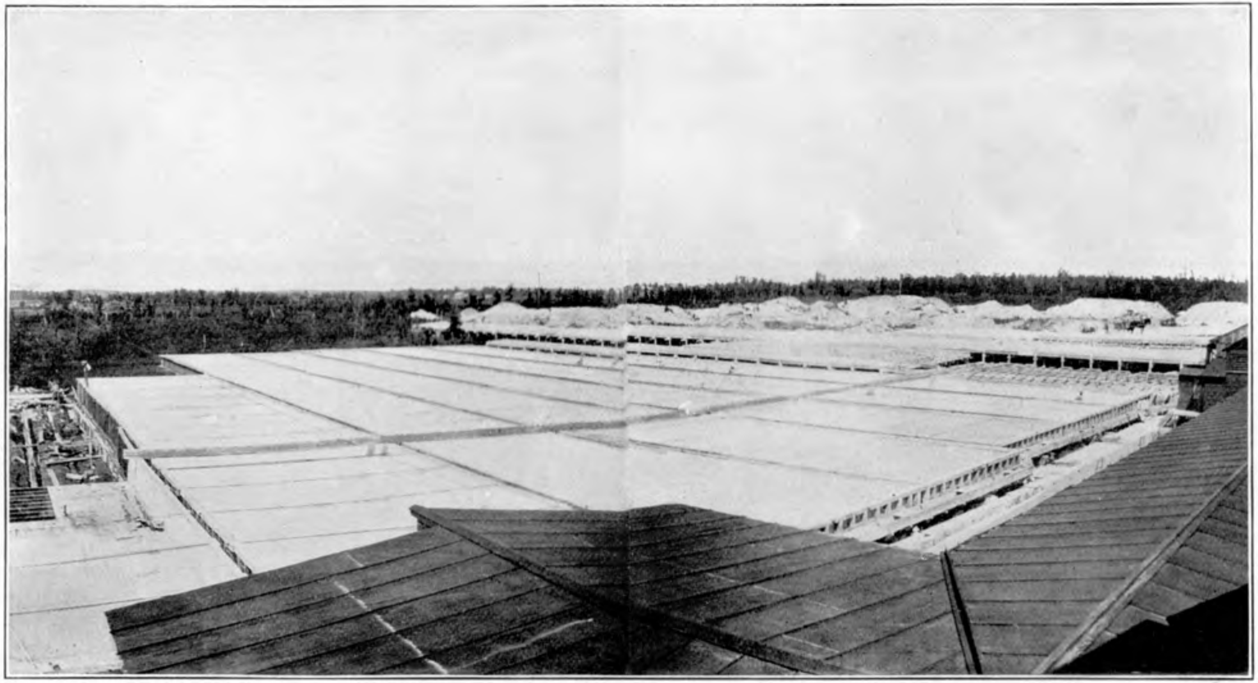
The clay which occurs on the farm of **Robert Dunlap** was especially examined and found to be of excellent quality. The clay is high in aluminum and comparatively low in the alkalies. This clay is not used at the present time but will undoubtedly be developed for some purpose in the near future.

Laboratory Examination.—The clay was examined in the laboratory and found to be hard when dry and very plastic when wet. It has a sour taste due to the presence of aluminum sulphate.

Under the microscope the clay is seen to consist of grains having irregular outlines, none of which are over .14 mm. in diameter. A greater part of the clay consists of grains under .004 mm. in diameter. The identification of the minerals is obscured by the iron oxide stains, although quartz and kaolin are recognizable.

The following analyses give the chemical composition of the clay. Number I is the reddish brown clay and Number II is the blue:

	No. I.	No. II.
H_2O, C_1	18.03	4.15
SiO_2	40.09	62.59
Al_2O_3	11.87	17.42
Fe_2O_3	4.00	5.88
CaO	10.29	None.
MgO	7.15	1.24
Na_2O	0.86	0.52
K_2O	2 74	8.08
TiO_2	0.75	0.30
SO_3	....	trace.
Total	99.78	100.18



SUPERIOR CHINA CLAY WORKS, HERSEY.

SETTLING VATS; CAPACITY 2,500,000 GALLONS.

MISCELLANEOUS LOCALITIES.

The clay or shale deposits which occur at Durand, Black River Falls, Eau Claire, and other places are not as promising as those at Merrillan. The clay occurs in thinner layers and there is consequently a greater percentage of quartz sand.

At Fond du Lac in Douglas County the deposit is a thinly laminated shale having a total thickness of from eight to ten feet. The shale has never been developed. It is situated near Superior and Duluth and ought to prove valuable for the manufacture of brick.

The following is a chemical analysis of the clay and it will be seen that the proportions of alumina, silica, and the fluxes are such as to warrant the supposition that a good building brick could be manufactured therefrom.

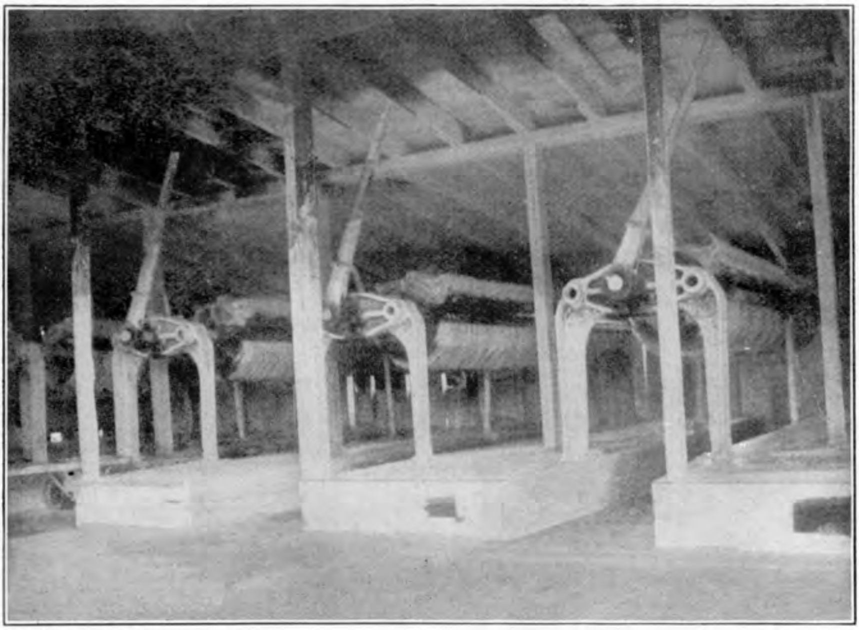
H_2O	6.18
SiO_2	58.19
Al_2O_3	18.77
Fe_2O_3	7.90
CaO	0.59
MgO	3.92
Na_2O	0.10
K_2O	3.78
TiO_2	0.55
MnO	Strong trace.
Total	99.98

CHAPTER XV.

FUTURE DEVELOPMENT OF THE CLAY DEPOSITS OF WISCONSIN.

Although brick and stone have been used in Wisconsin for a great many years in the construction of public buildings and business blocks, they have not been used very generally in the construction of residences. The forests have furnished a much cheaper and more easily obtainable material and throughout the length and breadth of the state it has been an almost universal custom to construct houses out of pine lumber. In the places where lumber has been less abundant and brick have been a common commodity residences and business blocks have in part been built out of the latter material. However, the brick have as a rule been made without regard for beauty and the houses are void of artistic features. Common brick, irregular in size and with uneven, coarse faces, can scarcely be appealed to as things of beauty. Only within the last few years have ornamental brick been used to any extent in this state. Common brick are entirely satisfactory for concealed portions of masonry work, but for fronts to buildings and other exterior parts, pressed brick and terra cotta should be used almost exclusively.

The quantity of lumber available in Wisconsin is decreasing each year and the prices have risen very rapidly. At present it is not difficult to foresee a time when lumber will be scarcer and more expensive than brick and terra



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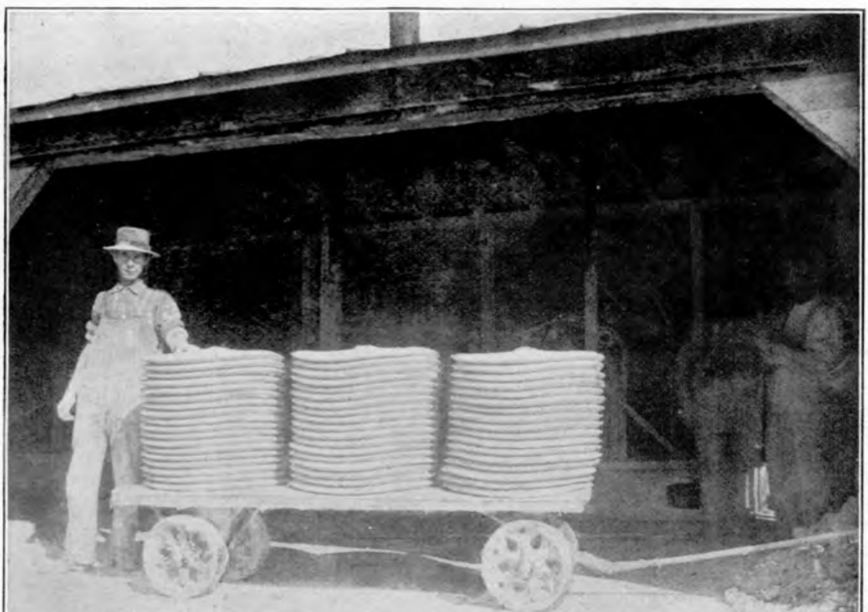

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SUPERIOR CHINA CLAY WORKS, HERSEY.

FIGURE 1.—SECTION OF PRESS ROOM SHOWING FOUR OF THE TEN FILTER PRESSES.

FIGURE 2.—TRUCK OF CLAY AS IT COMES FROM THE FILTER PRESSES.

cotta. While the price of lumber has been advancing the price of brick has on the whole been going down. The improved methods of brick manufacture and the discovery of enormous quantities of clay have not only tended to lessen the cost of production but have also improved the quality of the brick.

Wisconsin possesses clays which are adapted to the manufacture of all kinds of brick. There are but few localities which do not have clay that will make a common brick. There are several localities in which pressed brick of the ornamental type can be made to advantage and it is anticipated that soon this branch of the brick industry will have a much greater development than at present. Improved methods of manufacturing common brick will undoubtedly be constantly sought after but the field of greatest development lies in the direction of ornamental brick.

Drain tile have been used quite generally in the southern part of the state but the people of the north have not as yet seriously undertaken the task of draining large tracts of now useless swamp land. In the near future there will be a much greater demand for drain tile in this section of the state.

Paving brick and sewer pipe are now obtained exclusively from neighboring states. Attempts which have been made to manufacture vitrified wares in Wisconsin have thus far been failures. However, most of these trials have been made with a class of clays which are the least suitable of any that occur within the state. Enormous quantities of paving brick and sewer pipe will be consumed in Wisconsin, alone, during the next ten years and it will be well worth time and money to experiment with every clay which offers any possibility of being suitable for the manufacture of these products. The most promising region in which to search for materials suitable for manufacturing these products is through the central part of the state where the pre-Cambrian shales occur.

The shales which occur along the Eau Claire River give evidence of being well adapted for this purpose. Some of the shale and clay which occur in the vicinity of Black River Falls in Jackson County, at Fond du Lac in Douglas County, at Menomonie in Dunn County, at Whittlesey in Taylor County, and at other localities are almost equally as promising. It is thought that these clays, some of which are not now being used, will soon be developed and that the chief products of the plants constructed will be ornamental and paving brick. The shales are very complex mineralogical and chemical compounds and can only be worked successfully for the manufacture of paving brick by the most careful and painstaking methods. The clays and shales at some of the above mentioned localities are rather low in aluminum and for this reason may prove to be unsuitable for making the best quality of vitrified ware.

For the manufacture of the finer porcelain wares there is an abundance of very plastic white kaolin and pure silica in Dunn and St. Croix Counties. Both are the very best products that are mined in this country today. In this region power is cheap but fuel is comparatively high. The markets of the northwest are open to any company that may locate in this kaolin region. Before many years it is hoped that someone will take advantage of these conditions and establish a much needed pottery.

Many of the clays within the state are suitable for the manufacture of earthenware. The purer deposits of lacustrine clays in the east and the alluvial deposits of the southern and central counties are well adapted to the manufacture of flower pots, cheap cuspidors, and similar earthenware products.

In general, there are vast opportunities in Wisconsin for the development of the clay resources. Not brick alone, nor tile, nor sewer pipe, but earthenware and porcelain manufactories are among the future possibilities.

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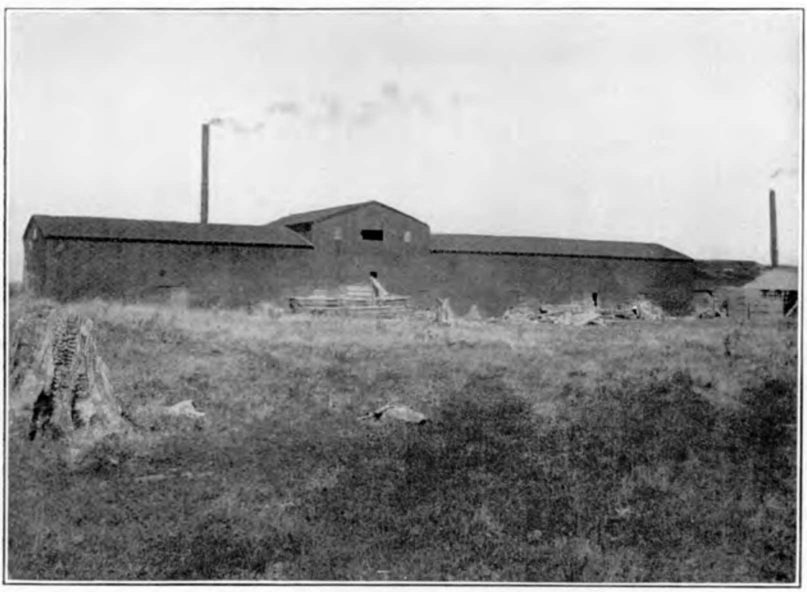

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SUPERIOR CHINA CLAY WORKS, HERSEY.

FIGURE 1.—CLAY LOADED ON CAR READY TO ENTER DRIER.

FIGURE 2.—WAREHOUSE; CAPACITY 4,000 TONS.

APPENDIX I.

METHODS EMPLOYED IN THE EXAMINATION OF THE CLAY DEPOSITS.

IN THE FIELD.

Nearly all of the clay deposits described in this report have been examined as they occur in the field. The depth of covering, thickness of the different kinds of clay, and the occurrence of boulders, gravel, and similar impurities were carefully recorded. Note was made of the position of the clay with respect to the rivers and lakes, the distance of the plant from railroad facilities, and the economy of the methods of manufacture as employed at the brick and tile factories now in operation.

Typical samples from one or more parts of the bank were collected and shipped by the owner to the laboratory for testing. These samples usually consisted of twelve to fourteen inch cubical blocks and were taken as they occurred in the bank. Samples of the sand used for moulding and mixing with the clay were also sent to the laboratory for examination.

IN THE LABORATORY.

Small samples were taken from the large boxes in the laboratory and carefully examined under a compound microscope to determine the physical and mineralogical characteristics of the clays. The bulk of the clay was very carefully mixed and quartered, a small portion being set aside for the chemical analyses, the remainder being retained for making physical tests.

The physical tests have not yet been completed and the discussion of this phase of the subject is deferred until the publication of the second part of the bulletin.

The chemical analyses have been performed and computations of the rational analysis made. The method of making these determinations is given below in the report of Mr. S. V. Peppel, chemist for the Survey.

THE CHEMICAL ANALYSES.*

Method of Sampling.

The clays which were obtained from the various companies in the state were dried sufficiently so that they would break up readily and then carefully sampled in the following manner:

The clay was spread on an oil cloth and broken up with a wooden mallet on a cement floor. After the sample had been reduced to particles the size of a grain of wheat it was thoroughly mixed and quartered until a sample of about one-fourth of a pound remained. This was again crushed and quartered until there remained about thirty grains, which was ground very fine in a porcelain mortar. By handling the sample in this manner no extraneous material was introduced unless through the abrasion of the mortar which would only increase the percentage of silica.

Moisture.

Many of the clays were so moist when received in the laboratory that they could not be sampled without first drying artificially. Under these conditions determination of the hygroscopic water could not have much significance. To the practical clay worker, unless he is using clays which are dried at a uniform temperature, the determination of

* By S. V. Peppel, Chemist.

the free moisture is of no value because of the constantly changing conditions of the atmosphere which leave the clay saturated with water one day and almost dry the next. Therefore it was thought best to dry all the samples at a temperature of 110° C. for one hour and bottle. The samples thus dried were not allowed to stand any considerable time before being used. From a scientific standpoint it may be preferable to determine the free or hygroscopic moisture by drying a weighed portion one hour at 110° C. and computing the percentage of loss by weight. When a determination of the hygroscopic moisture is made, the percentages in the analysis should be calculated on the basis of the dry sample.

Loss on Ignition.

Two portions weighing one gram each should be weighed out of the thirty gram sample. The operator should exercise great care in selecting and weighing these portions in order that they shall represent the average composition of the sample. A weighing tube, while desirable in many ways, should not be used unless the sample has been carefully sized through a 100 to 120 mesh sieve, since the coarser particles will be poured out first. Even when carefully sized the heavier minerals or those having the highest specific gravity will leave the tube first, so that two samples weighed from the same tube will not give identical analyses. The plan followed in this report was to spread the entire sample on a clean piece of glazed paper, mix thoroughly with a spoon or spatula and take small portions of clay from all parts of the pile and place directly into the pan and weigh. This method will yield all the duplicates desired.

The loss on ignition is determined by heating one of the one gram samples in a platinum crucible of known weight for twenty or thirty minutes over a Bunsen burner and for thirty to forty-five minutes over a blast or until the weight is constant. The loss occasioned thereby represents the combined water, or water of crystallization, organic matter, carbon dioxide, and sulphur dioxide. The other one gram portion is placed in a second platinum crucible for fusion. This second portion is not altogether necessary since the residue after loss on ignition of the first sample may be used equally as well. To the ignited or fresh samples, whichever is used, add one-fourth to one-half gram of nitric acid and eight grams of sodium carbonate, place it over a Bunsen burner in an inclined position (5° to 10°), cover, and raise the heat gradually for ten to fifteen minutes until the highest heat attainable is reached. The sample should remain over the burner fifteen minutes or more but not necessarily until the sample has completely melted or become quiet. The crucible containing the sample is then placed over a strong blast where it is left for about five minutes after all bubbles have ceased to be given off and the mass has become very fluid. The lid is then carefully removed from the crucible and turned upside down on a clay triangle stool or other convenient support which will not attack hot platinum. The crucible is lifted with tongs and the fluid caused to rotate and mix in the crucible so that any undecomposed mineral particles will be detached and taken into solution. The operator should continue to rotate the crucible so that the fusion while cooling will be spread over as much of the *inside* surface of the crucible as possible which will facilitate its removal by water. When the fusion has solidified, plunge the crucible into cold distilled water as far as possible without wetting the inside. This sudden cooling of the fusion causes it to crack so that it can be more easily removed from the crucible.

When cool the crucible and lid are placed in a four inch casserole covered or nearly covered with hot distilled water, and removed to the hot plate where the temperature is maintained just below that which will cause bumping. Here the fusion is given time to soak loose from the crucible. After the fusion has softened, a glass rod may be used to loosen it. The rod, however, must be used with the greatest care or the crucible will be injured by scratching or indenting.

Determination of the Silica, SiO_2.

After the fusion has been loosened from the crucible both the crucible and lid are washed off with hot water and the last traces of the fusion in the crucible are dissolved with a very little hydrochloric acid. In case the crucible or lid is stained with iron, as often happens, add hydrochloric acid to the crucible, cover and warm gently. The volatilized hydrochloric acid condensing on the lid and sides will remove the stains. This and the washings are added to the fusion care being exercised to avoid loss by spattering when the acid comes in contact with the alkali of the fusion. If any of the fusion is still hard let the casserole remain on the hot plate until by crushing and soaking it is all soft. If the next step, which is the addition of hydrochloric acid, be taken while the fusion is hard and lumpy, the silica thrown out by the hydrochloric acid tends to form a coating over a part of the soluble salts and thus protects them from solution. The result is an impure silica which gives a high residue of volatilization.

The cover glass is kept on the casserole and hydrochloric acid is added until the color of chloride of iron develops after which about five to ten c. c. more is added and the carbon dioxide boiled out. A few minutes boiling is ordinarily sufficient. The cover is then removed and the spatters washed into the casserole. The casserole is placed on a water bath, evaporated to dryness, and freed from odor of hydrochloric acid. Dissolve in fifteen c. c. of hydrogen hydroxide, let it set five to thirty minutes, working acid to all parts of the casserole, add hot water until the casserole is about two-thirds full, cover, boil hard for a few minutes to make the silica more granular, allow silica to settle, filter through a 9 cm. ashless filter and wash with hot water. Place the filtrate and washings on water bath in the same casserole, evaporate to dryness again, add hydrochloric acid as before and two or three drops of nitric acid, boil, filter, and wash as before, using a tall beaker of about 450 c. c. capacity. The nitric acid added above was to insure the complete oxidation of the iron and avoid the necessity of boiling just before precipitating with ammonium hydroxide. This saves much time and avoids the danger of loss from bumping while boiling in the beaker.

The precipitate of silica which may contain traces of iron chloride, calcium chloride, titanium oxide, and phosphorous pentoxide, is now removed* and ignited either wet or dry. If wet, care must be taken to avoid snapping out by using a very small flame until dry. To ignite either the wet or dry precipitate the filter paper is taken up and folded so as to envelop the entire precipitate. It is then placed in the bottom of a platinum crucible so that the paper will not fly open when heated. The crucible is inclined at an angle of about forty-five degrees and ignited gently over a Bunsen burner until the paper is entirely consumed. The heat is then increased until all within the crucible is white. It is then removed to the blast and heated to constant weight. If the silica is as high as 70 per cent it may require half a day over the blast to bring to constant weight. For this precipitation and for all others that are to be weighed ashless filters should be used.

Volatilization of Silica, (SiO_2).—After the above precipitate has been ignited and weighed as above described the silica is moistened with a few drops of water from a spritz flask, care being taken not to blow out any of the precipitate from the crucible with the air which precedes the flow

* Many prefer, for silica determination, evaporating to dryness once on water bath and baking in a hot air oven, at 110° to 115° C., until free from hydrochloric acid, instead of taking to dryness twice. However, the method described was followed for several months, and our experience would indicate that the residue from the volatilization of silica and the silica left with the ferric oxide and alumina are both smaller than by the customary method.

of water. Add ten drops of strong sulphuric acid and one-fourth to one-third of a crucible of hydrofluoric acid.* Heat at a very low temperature until dry, ignite strongly over the Bunsen burner for fifteen minutes and over the blast for ten minutes, cool and weigh. Deduct the weight of the residue from the total weight of silica and add to weight of ferric oxide and alumina, both of which should be ignited in same crucible. Should milky opalescence appear near the end of the evaporation of the hydrofluoric acid it is very good evidence of the presence of both titanium oxide and phosphorous pentoxide in appreciable quantities.**

If no errors have been made in the preceding work the volume of the first filtrate, about 200 to 250 c. c. which contains the possible iron, aluminum, manganese, calcium, magnesium, and the salts due to the fusion, will be about right for the precipitation of $Fe(OH)_3$ and $Al(OH)_3$.

Determination of the Ferric Oxide, (Fe_2O_3) and Aluminum Oxide, (Al_2O_3).

Ordinary Method.—Heat the above filtrate, add a light excess of ammonium hydroxide, and boil for a few minutes. While raising to a boiling temperature do not allow the precipitate to settle, otherwise there is danger of breaking the beaker. After boiling allow the precipitate to settle and then draw off a portion of the filtrate by decantation into a 500 c. c. beaker and set aside for further determinations.

If any of the precipitate is drawn over it must be filtered out, washed, and weighed with the iron and alumina. The

* Hydrofluoric acid makes a very poisonous burn and therefore should be added with caution to the contents of the crucible which are now warm from the action of the sulphuric acid on the water. Care should also be exercised to avoid breathing the fumes of the hydrofluoric acid which are given off freely when it is added to the contents of the crucible.

** Hildebrand, Bul. 148, U. S. G. S., pp. 38 and 40.

precipitates consisting of $Al(OH)_3$, $Fe(OH)_3$, TiO_2 and $P_2 O_5$ should be washed four or five times by decantation with *hot* water. The washings should be placed in a ten or twelve inch evaporating dish and concentrated.* Dissolve the washed precipitate in hydrochloric acid, add two drops of nitric acid, boil, and precipitate with ammonium hydroxide as before, adding all washings to those in the evaporating dish. If during the washing the precipitate does not settle readily add a few drops of nitric acid.

It is preferable to wash by decantation, as above described, because no time is lost in boiling out the excess of nitric acid. The small amount of precipitate which may chance to be drawn over into the evaporating dish does not vitiate the results since all nitric acid is boiled out in the concentration, and the precipitate which comes over is dissolved and re-precipitated. Some chemists prefer to wash several times by decantation and then throw on a filter and complete the washing by suction. The nature of the precipitate is such, however, that, unless suspended in water, it will adhere closely to the channel, thus preventing complete washing although the washings may show no trace of chlorine.

When washed the precipitate is transferred to an eleven centimeter filter and drained. Any particles which may adhere to the beaker are dissolved with a little hydrochloric acid and added to the washings. Add one drop of nitric acid to the washings, concentrate to 30 to 50 c. c. and wash out into a small beaker.

Precipitate with ammonium hydroxide, avoiding more than a slight excess, boil, filter on a small filter, and wash, allowing filtrate and washings to run into the first portion which was drawn off by decantation. If the work has been

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* A very convenient instrument for these decantations is a siphon made by attaching a few inches of soft rubber tubing closed with an ordinary pinch cock to the longer arm of a bent glass tube. Use the same siphon throughout the determination. It need only be charged once for each determination.

carefully executed the total volume of this filtrate ought to be about 200 to 300 c. c.* The precipitate which was obtained may be ignited when wet but there is less danger of accident if dried first. The ignition is performed in the same manner as described above for silica. When the percentages of $Fe_2\ O_3$ and $Al_2\ O_3$ are high this ought not to require over one hour and a half.† This ignited precipitate contains Fe_2O_3, Al_2O_3, P_2O_5, TiO_2, and traces of SiO_2.

Bisulphate Fusion.

To obtain the silica from this precipitate, make a second titration for $Fe_2\ O_3$, and determine TiO_2. The precipitate should be mixed with about 6 grams of $KHSO_4$, slowly heated and fused in the same crucible. In fifteen minutes the fusion should be liquefied. Should the precipitate float on the fluid bisulphate or adhere to the sides of the crucible, it should be washed down by rotating the crucible gently without removing the lid. Increase the heat gradually until the fusion has a faint red color. This will require from one to two hours, depending upon the quantity of water contained in the bisulphate. Continue heating until no black specks are visible and the fusion boils quietly. The heat should be increased very carefully owing to the tendency which this fusion has to boil over. If the bisulphate is satisfactory this fusion requires very little attention and ought not to consume more than three hours. Much of the bisulphate, however, is not entirely free from water and for this reason the fusion may require five or six hours and almost constant care to keep it from frothing over the sides. When looking into the crucible during fusion the lid should be kept above the crucible so that it may catch any particles which may be thrown upwards. The fusion

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* If the calcium oxide is low 200 c. c. is the right quantity; if high, 300 c. c.

† For precautions in igniting this precipitate, see Talbot's Quantitative Chemical Analyses, p. 30.

should be hot enough to expel the sulphur dioxide fumes when the lid is raised.

After the fusion is complete the crucible is inclined about 45° and cooled. The fusion is detached from the crucible by adding a little water and then transferred to a small beaker. The crucible is washed clean with a little hot water and 60 c. c. of dilute sulphuric acid ($\frac{1}{4}$ of H_2SO_4 to 4 H_2O) is added to the fusion. This mixture ought to stand over night but if used immediately should be warmed until dissolved. Filter, ignite, weigh, and volatilize the silica with hydrofluoric acid. Add the loss of weight to silica as a correction and deduct from total weight of Fe_2O_3, Al_2O_3, etc.

Ferric oxide, (Fe_2O_3) by $KMnO_4$ titration.

Add 10 c. c. of sulphuric acid to the filtrate, warm and pass through a modified Jones reductor,* which has been previously prepared by pouring a funnel full of warm di-dilute sulphuric acid and pour through the reductor. Pour 200 to 250 c. c. more through the reductor to wash it out and leave a little in the funnel. Titrate the iron with standard $KMnO_4$ while warm. If air is allowed to get into the reductor the result is unreliable and it must be thoroughly washed with dilute sulphuric acid before making another determination.

Determination of Titanic Acid (TiO_2).

To estimate the titanium transfer the solution in which the Fe_2O_3 was determined into a 500 c. c. flask and make up to exactly 500 c. c. Mix thoroughly and pour out 100 c. c. into a Nessler tube. To this portion add seven to eight c. c. of strong sulphuric acid and about two c. c. of hydrogen hydroxide. Prepare a standard by taking a little less than 100 c. c. of distilled water and add seven to eight c. c. of

* The modified Jones reductor is described by A. A. Blair in "Chemical Analyses of Iron. 3rd Edition, p. 96.

strong sulphuric acid, two c. c. of hydrogen hydroxide, and sufficient standard TiO_2 to make the solution the same color as the sample. If necessary add distilled water until the volume of the solution in both tubes is the same. Compare the color with that of the solution to be estimated, taking precaution to observe both under the same conditions of light and depth. Add sufficient TiO_2 solution to bring the standard to the same color as the solution estimated. Observe the number of c. c. of standard solution used and calculate from this the weight of titanic oxide in the sample.

If the color of the fusion shows more than a trace of manganese it will be necessary to make the first precipitation of iron and alumina by the basic acetate process which is as follows:

Determination of Iron and Alumina as Basic Acetates.

In taking up the second silica evaporation in hydrochloric acid add three or four drops of nitric acid and 15 c. c. of dilute hydrochloric acid (3 of HCL to 2 H_2O), boil, allow SiO_2 to settle and finally filter and wash. To the cold filtrate cautiously add solid Na_2CO_3 keeping cover over the beaker until the appearance of a reddish brown color. Then add a solution of Na_2CO_3, drop by drop, until the precipitate which is formed is not dissolved by vigorous stirring and allowing to stand. Add hydrochloric acid drop by drop and stir vigorously, allowing it to stand two or three minutes between drops until the precipitate dissolves. Only two or three drops should be required for this purpose. Add one-fourth to one-half c. c. acetic acid and one to one and a half grams of sodium acetate and bring to a boil quickly. Boil briskly for not more than ten minutes taking precautions against bumping before ebolution begins. Let the precipitate settle and carefully draw off a portion of the filtrate into a beaker in which calcium is to be precipitated. Wash four or five times with hot water by decantation, concentrating the washings as in the case of the ammonium hydroxide precipitation. If the water becomes cold while washing a small part of the acetate precipitate will be taken into solution and the filtrate will become cloudy. Transfer the precipitate to an eleven centimeter filter and wash twice with hot water. Return the precipitate to the original beaker by using a stream of hot water. Wash the filter first with dilute hydrochloric acid and then with water, turning the washings into the beaker which contains the precipitate. Preserve the filter for draining the subsequent NH_4 OH precipitate. Dissolve the basic acetates in hydrochloric acid and add a few drops of HNO_3. Boil and proceed in the second precipitate according to the ordinary process of precipitation of Fe $(OH)_3$ and $Al(OH)_3$ by NH_4 OH.

Determination of the Oxide of Manganese. (MnO.)

If the combined washings from the iron and alumina are more than 250 c. c. they should be concentrated to about this volume. To this cold filtrate sufficient NH_4OH should be added to make it slightly alkaline. Add eight to ten drops of bromine, stir, cover, and allow to stand, adding a little bromine water from time to time until the manganese has separated out. Boil until all the bromine is expelled and filter, washing the precipitate thoroughly with hot water. Ignite the precipitate and weigh in a porcelain crucible as $Mn_3 O_4$ and calculate MnO. In this ignition as in all others here described be careful to avoid reducing conditions.

In case there is from three to four per cent of manganese the precipitate should be treated as directed by Blair in "Chemical Analysis of Iron," 3rd edition, p. 112. By this method the manganese is dissolved and re-precipitated as manganese ammonium phosphate.

Determination of the Calcium.

If the combined filtrates from iron, aluminum, and manganese are much more than 250 c. c. concentrate to that volume. Bring the filtrate to the boiling point and precipitate calcium by adding to the boiling solution 40 c. c. of a saturated boiling solution of $(NH_4)C_2O_4$ diluted with an equal volume of water. Remove the solution to a warm place and allow it to stand from five to thirty minutes. By this time all the calcium should be precipitated and the solution clear. If the quantity of calcium is six per cent or less the solution may be filtered, washed thoroughly in hot water, and ignited over a Bunsen burner and blast to a constant weight, which may require two or three hours. The calcium is then weighed as calcium oxide, CaO. On account of the hygroscopic nature of calcium oxide, the weighing should be made as soon as it is cool. When reigniting the calcium oxide it should be kept over the blast at least one or one hour and a half, otherwise the weight obtained may be higher than in the first instance.

If the filtrate should contain more than six per cent of calcium it should be filtered and washed with hot water. The bulk of the precipitate should be transferred with a stream of hot water to the beaker in which the precipitation was made. The precipitation is then dissolved by adding dilute hydrochloric acid (1:1) through the filter into the beaker containing the precipitate and the filter is thoroughly washed with hot water. To the dissolved precipitate add 5 to 10 c. c. $(NH_4)_2C_2O_4$ and re-precipitate with NH_4OH, avoiding any excess. Filter through a weighed gooch crucible, wash with hot water, and dry at 110° to 115° C. to constant weight (1 to 1½ hours). Weigh as $CaC_2O_4 H_2O$ which contains 0.3836 CaO.

As far as is known this method of weighing calcium has not been in general use by commercial chemists. Fresenius gives the composition as $CaC_2O_4 H_2O$ when dried at 100° C. and we have repeatedly checked to within .02% and closer by dissolving and re-precipitating, weighing both as the oxide and the sulphate.

The oxalate of calcium above obtained may be converted into the sulphate and weighed as described by Professor N. W. Lord in "Notes on Metallurgical Analysis," p. 11, or as described by W. H. Hess in the "Journal of the American Chemical Society," Vol. XXII, p. 477. However, the previously described method has been found to be fully as accurate and is much more rapid.

If calcium is high it is absolutely necessary to re-precipitate. The first precipitate of CaC_2O_4 always contains some magnesium which is re-dissolved as a part of the filtrate when the second precipitation is made.*

Determination of Magnesium Oxide. (MgO.)

The combined filtrates are rendered slightly acid by the addition of hydrochloric acid and then concentrated to 200 to 400 c. c. according to the amount of magnesium expected. The filtrate is thoroughly cooled and 10 c. c. of strong NH_4OH are added. The magnesium is then precipitated by adding drop by drop a saturated solution of NaHPO, at the same time stirring the filtrate. If the magnesium is under five per cent, from 4 to 6 c. c. will be sufficient. If it is much higher from 9 to 11 c. c. will be required. The solution should contain about one and a half times the amount of Na_2HPO_4 needed to precipitate the magnesium. A considerable excess of Na_2HPO_4 tends to retard precipitation and if very great, it may even prevent complete precipitation. After the reagents are added the solution should be stirred vigorously until it is evident that all the magnesium is precipitated. This will require from three to ten minutes. Add to the solution one-tenth of its volume of strong (90%) NH_4OH, stir well, and let it stand for ten or twelve hours. Filter through a weighed gooch crucible, wash with the solution for wash-

*See W. Crooks' "Select Methods in Chemical Analysis," p. 51.

ing magnesia described under solutions, and ignite to redness over the Bunsen burner. Place the precipitate over the blast for ten minutes and weigh as $Mg_2P_2O_7$. If all the magnesium has not been precipitated it will show after standing for a short time. This precipitate probably acts slightly on the platinum crucible in which it is ignited, but not to such an extent as to vitiate the determinations. The magnesium ammonium phosphate may be filtered in a paper filter and ignited to $Mg_2P_2O_7$ in a porcelain crucible using a little HNO_3 to aid in oxidizing the filter paper. The weight of the MgO equals the weight of the $Mg_2P_2O_7 \times$ 0.36212.

J. Lawrence Smith's Method of Alkali Fusion.

Unless it is suspected that the alkalies are very low, 0.5 grams of the clay is mixed with a trifle over 0.5 grams of NH_4CL and well ground. Weigh out six grams of $CaCO_3$, coat the bottom and sides of a platinum crucible with a portion, and keep out sufficient for a thin coating on top of the clay, and mix the balance with the sample in the agate mortar. Transfer the sample to the crucible and cover with the $CaCO_3$ reserved for the purpose. A tight fitting lid is then placed on the crucible and it is heated gently until the excess of NH_4CL is volatilized. Usually five minutes is sufficient. The lower half of the crucible is then heated to dull redness and the temperature held at that point for about one hour. Cool and remove the sintered mass to a four inch casserole. Should the mass stick to the crucible a little water may be added to set it free. Never gouge it out. Set the fusion on a cool part of the hot plate to digest.

Wash out the crucible with hot water. Add 5 to 10 c. c. of strong hydrochloric acid, cover and warm to remove traces of iron. When the solution is complete wash the crucible into a small beaker and preserve the washings for the subsequent determination of iron. When the fusion has thoroughly disintegrated, which may be aided by using a heavy glass rod or porcelain pestle, wash five times by decantation through an eleven centimeter filter using only a small quantity of water each time and bringing it to a boil before filtering. Transfer the precipitate onto a filter and wash until a five-inch casserole has been filled with the washings.

Combined Chlorides. (KCl and NaCl.)

Concentrate the filtrate to about half its volume and add several grams of solid $(NH_4)_2 CO_3$.* When the solution has become quiet boil and concentrate to 30 or 40 c. c. Add a few drops of NH_4OH and a little more $(NH_4)_2 CO_3$ either dry or in solution. Filter through a nine centimeter filter into a four inch casserole and wash with hot water until the casserole is full. Concentrate to 5 or 10 c. c., add two drops of NH_4OH and five to six drops of newly prepared saturated solution of $(NH_4)_2 CO_3$, and filter through a seven centimeter filter into a platinum dish. Wash with small quantities of hot water until the volume is increased to about 100 c. c. Evaporate to perfect dryness on the water bath, and ignite to expel ammonia salts, taking care to avoid snapping. Heat until the salts just fuse and not beyond a dull red. Take up in a little water and add one drop of NH_4OH and three drops of $(NH_4)_2 CO_3$. Filter into a tared platinum dish, wash until the volume is increased to 75 or 100 c. c. and add three to four drops of HCl. Evaporate to dryness on a water bath and add a little water. If all the salts do not dissolve, filter, wash, add two drops of hydrochloric acid and evaporate to dryness again. If all dissolves, filtering is unnecessary. Add two drops of hydrochloric acid and evaporate to dryness, ignite, expelling ammonium salts, and heat to point of fusion of the double chlorides, and weigh observing the same precautions as before. Weigh as KCl and NaCl.

*Owing to the marked solubility of glass in a strong solution of ammonium carbonate it is much better to use the solid for the first and largest addition of $(NH_4)_2 CO_3$ to avoid the introduction of the alkalies from the dissolved glass.

Determination of the Potash. (K_2O.)

Wash the double chlorides into a small beaker. If not almost clear, filter and add two to four c. c. PtCl solution, depending upon the quantity of the double chlorides. Evaporate to dryness either on water bath or on a cool part of the hot plate, care being exercised to avoid spattering. Filter through a weighed gooch crucible and wash the precipitate with eighty per cent of alcohol, the first three or four times by decantation. Dry twenty-five minutes at 110° to 120° C., weigh as K_2PtCl_6 and calculate K_2O. Also calculate the KCl and deduct from the weight of the combined chlorides (KCl + NaCl). This will leave the weight of the NaCl from which the Na_2O is calculated.

Unless the reagents used in the alkali determinations are known to be absolutely pure a blank must be run along with each determination, provided the blank is not already known.

$$\text{Weight of } K_2O = \text{Weight of } K_2PtCl_6 \times 0.19395$$
$$\text{Weight of } KCl = \text{Weight of } K_2PtCl_6 \times 0.30696$$
$$\text{Weight of } Na_2O = \text{Weight of } NaCl \times 0.53077$$

Determination of Ferric Oxide (Fe_2O_3) by $K_2Cr_2O_7$ Titration.

Ferric oxide may be determined by removing the bulk of the fusion from the filter and dissolving in hydrochloric acid, traces from the filter being dissolved with the hydrochloric acid kept from the cleaning of the crucible. Wash the filter six or seven times with hot water, keeping solution as small as possible. Add 40 c. c. hydrochloric acid, boil, reduce with $SnCl_2$, cool, add thirty to forty c.c. saturated solution $HgCl_2$ and titrate with standard $K_2Cr_2O_7$ solution, using a one per cent potassium ferri cyanide solution as an indicator. This indicator should be freshly prepared for each set of titrations.

Determination of the Sulphuric and Phosphoric Acids.

To determine sulphuric and phosphoric acids it is best to make another fusion, using two grams of the clay, fourteen to fifteen grams of Na_2CO_3 and one-half gram of KNO_3. Mix a greater part of the flux in the crucible with the clay and cover with the remainder to prevent the escape of oxidized sulphur. Proceed with the fusion almost as before. A five-inch casserole will be better for the extraction of this fusion. When thoroughly disintegrated wash several times by decantation through a filter and then throw the fusion into the filter and wash five or six times with hot water. Where both sulphur and phosphoric acid are low this treatment will dissolve all but very minute traces. Divide the filtrate into two equal parts, using calibrated, graduated flasks.

Determination of Sulphur. (S.)

Place one-half of the filtrate in a casserole, "and if the ebolution is colored by $Mn_2Na_2O_8$, add a few drops of alcohol. Filter and wash well with hot water. Add hydrochloric acid to the filtrate till just acid, and evaporate it to dryness carefully, and dry at 100° C. Now add 5 c. c. of HCl first diluted with its own volume of water. Warm and add 50 c. c. of H_2O, heat until all is dissolved but a little SiO_2, filter and wash. The filtrate should not exceed 100 c. c.; if it does, concentrate it. Now heat to boiling and add 5 to 10 c. c. of a ten per cent solution of $BaCl_2$ previously diluted with 10 or 20 c. c. of water and heated. Stir and let the precipitate of $BaSo_4$ settle."* When clear, filter into a weighed gooch crucible, wash with hot water, dry, ignite and weigh as Ba SO_4. Calculate the S or SO_3 as the case may require.

A blank fusion using one-half the amount of flux above given must be run at the same time and carried through

* N. W. Lord, "Notes on Metallurgical Analyses," p. 51.

just as the sulphur determination in order to get the correction necessary for the sulphur in the reagents and for that absorbed by them from the gas flame during fusion.

If soluble sulphates are to be determined, as will sometimes be the case, extract sulphates with hot water, add a few drops of HCl and $BaCl_2$ and proceed as before for sulphur determination.

Weight of Sulphur = Weight of $BaSO_4 \times 0.13756$
Weight of SO_3 = Weight of $BaSO_4 \times 0.34352$

Determination of Phosphoric Acid. (P_2O_5.)

Place the second half of the filtrate in a casserole, neutralize with HCl, and evaporate to dryness on a water-bath. Add 15 c. c. of dilute hydrochloric acid (3 HCl to 2 H_2O) and 60 c. c. of water, boil, filter, and wash.

The filtrate and washings from the insoluble SiO_2 should not exceed 150 c. c. "To this add 10 c. c. of conc. HNO_3, then NH_4HO until a precipitate is formed which does not disappear on stirring, then 3 c. c. of conc. HNO_3, which must redissolve the precipitate." "The solution will now be quite warm. Add at once from a pipette in a fine stream 50 c. c. of 'molybdic acid solution,' stirring the liquid vigorously all the time, and continuing this stirring for about three minutes. Let the solution stand in a warm place until it is clear and the precipitate has all settled (which should not require to exceed one hour), remove a portion of the clear liquid with a pipette and test it by adding a little more molybdic acid solution and warm to see if all the P_2O_5 is down.

Filter the liquid through a seven centimeter filter, transfer the precipitate to the filter and wash until free from iron, with a five per cent solution of ammonium nitrate *very slightly modified* with HNO_3." "When the precipitate is washed put the beaker, in which the precipitation was made, under the funnel and redissolve the precipitate on the filter with dilute NH_4HO. When dissolved and the liquid run through, wash the filter with water three or four times, then with a little dilute hydrochloric acid, and then again with water. The filtrate should now be clear and colorless. If it is cloudy or colored (by a little iron), add HCl until the liquid is acid (the yellow precipitate usually separates), then add four or five drops of a saturated solution of citric acid, then NH_4HO to make the liquid strongly alkaline. This will give a clear liquid, the citric acid holding the iron in solution.

Now add drop by drop a considerable excess of 'magnesia mixture,' stirring the liquid constantly. This excess must be estimated from the probable amount of phosphorus in the ore taken. Continue to stir the solution vigorously for four or five minutes, then add NH_4HO until the solution smells strongly of ammonia.

Let it stand until the precipitate of Mg NH_4PO_4 has settled completely (one or two hours). The precipitate should be *white and crystalline;* if red or flaky, the results will be inaccurate.

Filter on a small filter or better on a Gooch perforated crucible. Wash with water containing one-tenth of its volume of conc. NH_4HO and a little NH_4NO_3, dry, ignite and weigh as $Mg_2P_2O_7$."*

$$\text{Weight of } P_2O_5 = \text{Weight of } Mg_2P_2O_7 \times 0.63788$$

REFERENCES.

Bulletin 148, U. S. Geological Survey.
Notes on Metallurgical Analysis, N. W. Lord.
Chemical Analysis of Iron, A. A. Blair.

SOLUTIONS.

HCl for silica determinations—

Mix 3 parts of strong HCl with two parts distilled water.

* N. W. Lord, "Notes on Matallurgical Analysis," pp. 23–25.

Washing solution for magnesium ammonium phosphate—
Dissolve 50 g. NH_4NO_3 in water, filter, add 500 c. c. strong NH_4OH (Sp. G. 0.90) and make up to 5000 c. c. with distilled water.

Mercuric Chloride solution—
Make a standard solution using 60 g. to the liter of distilled water.

Ammonium oxalate solution—
Make a saturated solution, using 40 g. to the liter of distilled water, filter if necessary.

Sodium Hydrogen Phosphate solution—
Make a saturated solution, using 90 g. per liter of distilled water, filter if necessary.

Ammonium carbonate solution—
Saturated solution freshly prepared for each set of determinations.

Platinic Chloride solution—
Dissolve 23 g. of $PtCl_4$ in 250 c. c. distilled water and add 2 to 3 c. c. HCl.

Hydrogen Peroxide—
3% H_2O_2.

Molybdic Acid solution—
Dissolve 100 g. MoO_3 in 417 c. c. ammonium hydroxide (sp. g. 0.96). Pour this solution into 1250 c. c. HNO_3 (sp. gr. 1.20), with constant stirring. This solution should not be yellow. Use only a clear solution of MoO_3.

Magnesia Mixture—
Dissolve 22 g. calcined MgO in dilute HCl, avoiding an excess of HCl; then add an excess of MgO, and boil. Filter, wash once, and add to the filtrate 280 grammes NH_4Cl and 700 c. c. NH_4OH (sp. g. 0.96). Dilute to 2000 c. c.

SPECIFIC GRAVITIES.

H_2SO_4	Sp. Gr.	1.84
HNO_3	Sp. Gr.	1.42
HCl	Sp. Gr.	1.18
NH_4OH	Sp. Gr.	0.90

STANDARD SOLUTIONS.

Standard solutions of almost any strength may be used but where a number of determinations are required it is very convenient to use solutions which will obviate the necessity of making calculations. The standard solutions used by the Survey were made so that one cubic centimeter

of $K_2Cr_2O_7$ Solution = .01 g. Fe_2O_3
of $KMnO_4$ Solution = .01 g. Fe_2O_3
of TiO_2 Solution = .001 g. TiO_2

Standardization.—The solutions for iron were standardized against ferrous ammonium sulphate of known purity, prepared in the Survey laboratory.

A standard $(CO\ OH)_2$ solution was kept to check up the $KMnO_4$ solution before using it.

The $KMnO_4$ solution was made up some time before being standardized and its value did not vary appreciably from time to time.

The TiO_2 solution was prepared by dissolving TiO_2 in dilute sulphuric acid (8 H_2SO_4 to 3 H_2O) and diluting. It was standardized by reducing with hot nascent hydrogen, reoxidizing with standard $KMnO_4$ solution, evaporating a measured portion to dryness; igniting over a blast, and weighing as TiO_2.

A complete blank must always be run, including all the reagents used and the same amount of distilled water ordinarily used in the analysis of a clay. It is very seldom that a blank does not show that corrections must be made for impurities.

Desirable and Necessary Apparatus.

A hot plate is almost indispensable to rapid and easy work in clay analysis. A very convenient form and size is a piece of boiler iron about 12 x 16 inches, with four legs. It is a good plan to cover the top with a thin piece of asbestos board. A tin lined copper can of about one gallon capacity, with two tubes attached near the bottom for connecting rubber tubes, is very convenient for keeping hot water. This can be so placed that one of the rubber tubes may be used to give a jet of hot water for washing precipitates on the filters, using an ordinary pinch cock near the spritz end of the tube for control.

The Rational Analysis.

On account of the impure and highly feldspathic character of most of the clays dealt with in this report, the rational analysis as ordinarily conducted would have little significance. The treatment of the sample to drive out the clay substance may result in a loss of as much as twenty per cent of the feldspar contained in the clay.[1] It was therefore deemed best to calculate the feldspar and kaolin from the ultimate analysis, using the following percentage compositions of feldspars: K_2O, 16.9; Al_2O_3, 18.4; $6SiO_2$ 64.7; and Na_2O 11.8; Al_2O_3, 19.5; $6SiO_2$, 68.7; and kaolin Al_2O_3 39.5; 2 SiO_2 46.5; 2 H_2O 14; as given by Dana,[2] as a working basis.

All the potash and soda were figured to feldspar. The alumina required for the feldspar was deducted from the total alumina and the difference was taken as the starting point from which to figure the kaolinite substance. The difference between the total silica (SiO_2) and that required by both feldspar and kaolin gives the quartz and the silica in silicates other than those mentioned.

[1] Karl Langenbeck, "Chemistry of Pottery," pp. 9–10.

[2] "A Text Book of Mineralogy," pp. 371, 377, and 481.

These determinations will be very close except for the samples of shale from Halcyon, Grand Rapids, and Eau Claire. The microscopic examination of these clays revealed other silicates than those considered in the calculations. Therefore the volumes computed will be slightly low in the feldspathic constituent and a trifle high in kaolinite substance and quartz.

The factors used for feldspar were:

$$
\begin{aligned}
Al_2O_3 \text{ for } K_2O &= \% \, K_2O \times 1.0888 \\
SiO_2 \text{ for } K_2O &= \% \, K_2O \times 3.8284 \\
Al_2O_3 \text{ for } Na_2O &= \% \, Na_2O \times 1.6525 \\
SiO_2 \text{ for } Na_2O &= \% \, Na_2O \times 5.8221
\end{aligned}
$$

For kaolin:

$$
\begin{aligned}
SiO_2 \text{ for } Al_2O_3 &= \% \, Al_2O_3 \times 1.1772 \\
H_2O \text{ for } Al_2O_3 &= \% \, Al_2O_3 \times 0.3544
\end{aligned}
$$

Determination of the Refractory Quotient.

Bischof's refractory quotient was determined in order to show the relation existing between the quotient for these, for the most part impure clays of lower fire qualities, and the true pyrometric values which are to be determined later.

Bischof's formula is:

$$Q = \frac{\text{O in } Al_2O_3}{\text{O in RO}} \div \frac{\text{O in } SiO_2}{\text{O in } Al_2O_3}$$

In this formula, the O in RO must be multiplied by three to make it conform to the atomic weights that he used, and the O combined with the iron must be figured as being combined in the ferrous condition as FeO. Therefore the formula is better written

$$Q = \frac{\text{O in } Al_2O_3}{3 \text{ O in RO}} \div \frac{\text{O in } SiO_2}{\text{O in } Al_2O_3} = \frac{(\text{O in } Al_2O_3)^2}{(3 \text{ O in RO}) \times (\text{O in } SiO_2)}.$$

Factors:

O in SiO_2 = % SiO_2 × 0.5298
O in Al_2O_3 = % Al_2O_3 × 0.4696
O in FeO = % Fe_2O_3 × 0.2000
O in CaO = % CaO × 0.2853
O in MgO = % MgO × 0.3971
O in MnO = % MnO × 0.2254
O in K_2O = % K_2O × 0.1698
O in Na_2O = % Na_2O × 0.2571

TABLE No. I.—*Chemical analyses of Wisconsin clays.*

No.	Location.		Name of Factory.	H_2O, C.	SiO_2.	Al_2O_3.	Fe_2O_3.	CaO.	MgO.	Na_2O.	K_2O.	TiO_2.	MnO.	Total.
	City.	County.												
1	Baldwin	St. Croix.....	Undeveloped......................	7.43	61.89	18.84	6.06	0.45	1.29	1.22	2.12	0.63	0.17	100.10
2	Baraboo	Sauk	John Paddock............	17.03	49.39	8.99	2.10	12.56	7.48	0.74	1.90	0.30	Trace.	100.49
3	Beaver Dam...	Dodge	Beaver Dam Brick Works.	5.12	73.36	12 83	3.50	0.89	0.52	1.04	2.30	0.50	Trace.	100.06
4	Beaver Dam...	Dodge	Beaver Dam Brick Works.........	16.30	49.26	9.25	3.37	11.88	7.47	0.84	1.52	0.33	Trace.	100.22
5	Bl'k River F'lls	Jackson	Halcyon Pressed Brick Co	5.26	70.30	18.07	1.65	abs.	6.90	0.76	2 94	abs.	0.06	99.94
6	(9 miles north.) Bl'k River F'lls	Jackson	Undeveloped (Halls Creek).......	4.40	59.88	18.10	10.04	0.31	3.13	0.52	3.72	.....	Trace.	100.10
7	Bl'k River F'lls	Jackson	Undeveloped (Halls Creek).......	7.16	50.17	17.90	12.29	0.55	6.86	0.58	3.06	0.75	0.61	99.93
8	Bl'k River F'lls	Jackson	Halcyon Pressed Brick Co	3.68	72.30	16.06	0.35	0.26	1.50	0.40	5 23	None	Trace.	99.78
9	Bl'k River F'lls	Jackson	Halcyon Pressed Brick Co	6.22	55.87	19.60	9.22	1.05	3.71	0.32	3.93	......	0.06	99.98
10	Bl'k River F'lls	Jackson	Halcyon Pressed Brick Co	4.38	65.52	16.33	4.02	1.65	3.09	0.33	3.94	None	0.58	99.84
11	Bl'k River F'lls	Jackson	Halcyon Pressed Brick Co	3.86	67.96	17.25	2.27	0.67	2.07	0.38	5 81	None	Trace.	100.28
12	Bl'k River F'lls	Jackson	Halcyon Pressed Brick Co	9.10	61.22	13.98	4.66	3.76	2.03	1.32	3.44	0.43	....	99.94
13	Boltonville	Washington..	William Voigt......................	27.85	29.47	7.11	2.58	18.18	12.25	0.68	1.76	0.35	....	100.19
14	Boltonville	Washington..	William Voigt......................	27.03	29.87	8.01	2.78	17.21	12.22	0.68	1.82	0.46	....	100.08
*15	Bristol	Kenosha......	Bristol Tile Works................	15.19	46 96	12.79	4.40	10.15	6.27	0.52	3.64	0.50	....	100.42
*16	Bristol	Kenosha......	Bristol Tile Works................	15.40	49.79	11.92	4.60	9.30	5.18	0.26	3.32	0.50	....	100.27
17	Burlington.....	Racine	Burlington Brick and Tile Co.....	17.04	43.68	14.37	4.40	10.84	5.19	0.36	3.76	0.40	Trace.	100.04
18	Burlington.....	Racine	Burlington Brick and Tile Co.....	22.35	35.81	11.19	3.60	16.12	7.54	0.44	2.64	0.33	....	100.02
19	Chippewa Falls	Chippewa	J. B. Theriault....................	5.00	71.77	13.74	3.60	1.23	1.17	1.20	2.30	0.45	Trace.	100.46

*Analyses performed by Mr. W. S. Ferris.

20	Chippewa Falls	Chippewa	J. B. Theriault....................	3.51	74.36	11.77	4.42	1.14	0.69	1.22	2.14	0.48	Trace.	99.73
21	Duck Creek....	Brown.	The Duck Creek Brick Co	5.53	69.80	12.89	4.90	1.02	1.35	1.16	3.62	0.50	....	100.27
22	Duck Creek ...	Brown........	The Duck Creek Brick Co.........	16.57	47.02	8.51	3.20	14.28	6.25	0.98	2.69	0 38	....	99.88
23	East Tramway.	Dunn.........	East Tramway Brick Yard........	7.36	64.37	13.90	5.00	2.80	2.15	1.46	2.94	0.40	Trace.	100.38
24	East Tramway.	Dunn.........	East Tramway Brick Yard..	7.71	60.29	14 00	6.80	2.84	2.73	1.46	3.64	0.57	Trace.	100.04
25	East Tramway.	Dunn.........	East Tramway Brick Yard........	8.73	58 94	12.40	9.20	2.91	3.16	1.00	3.32	0.55	0.22	100.43
26	East Tramway.	Dunn.........	East Tramway Brick Yard........	7.64	61.02	15.59	5.12	3.22	2.49	1.26	3.34	0.52	Trace	100.16
27	Eau Claire.....	Eau Claire...	Undeveloped (Geo. T. Thompson)	3.79	75.66	12.19	2.57	0.82	.72	1 53	3.06	None	None..	100.34
28	Eau Claire.....	Eau Claire...	Undeveloped (Geo. T. Thompson)	9.41	49.86	27.41	4.43	0.48	2.10	0.52	5.30	None	.32	99.83
29	Eau Claire.....	Eau Claire...	Undeveloped (Geo. T. Thompson)	5.21	57.33	21.64	5.57	0.85	2 67	0.64	6.06	None	0.21	100.18
30	Eau Claire.....	Eau Claire...	Undeveloped (Geo. T. Thompson)	7.22	51.53	20.51	8.10	0.90	4.02	0.66	6.86	0.25	Trace.	100.00
31	Eau Claire.....	Eau Claire...	Undeveloped (Geo. T. Thompson)	3.14	47.00	35.26	3.03	none	0.28	0.31	0.64	0.25	....	99.91
32	Embarrass.....	Waupaca.....	Undeveloped......................	10.89	41.73	2.13	42.60	0.83	Tr'ce	0.40	0.87	0.30	....	100.04
33	Endeavor	Columbia	Endeavor Brick Yard	16.19	49.57	10.84	3.60	10.01	6.61	0.82	2.50	0.35	Trace.	100.49
34	Endeavor	Columbia	Endeavor Brick Yard	17.06	47.57	10.49	3.80	10.62	6.98	0.72	2.44	0.35	....	100.03
35	Fredonia.......	Ozaukee......	Carl Peterson......................	22.29	36.57	10.15	4.06	14.55	9.63	0.94	1.82	0.25	....	100.26
36	Ft. Atkinson...	Jefferson	Ft. Atkinson Brick Mfg. Co.......	24.82	33.48	8.95	3.50	16.32	9.68	0.76	2.08	0.27	Trace.	99.86
37	Ft. Atkinson...	Jefferson	Ft. Atkinson Brick Mfg. Co.......	25.29	32.66	8.73	3.20	16.93	9.64	0.86	2.30	0.30	Trace.	99.91
*38	Glenwood......	St. Croix	Syme, Baldwin & Co..............	4.58	73.14	11.64	5.00	0.97	0.88	1.30	2.38	0.45	0.18	100.52
39	Glenwood	St. Croix	Undeveloped......................	8.80	65.19	25.31	0.21	......	......	......	0.49	......	....	100.03
40	Grand Rapids.	Wood.........	Scott & Alexander................	4.69	52.52	14.65	18.07	0.94	2.40	0.34	5.52	1.35	Trace.	100.48
41	Grand Rapids	Wood.........	Scott & Alexander................	9.10	34.44	17.26	23.80	0.27	11.21	0.22	1.94	0 47	1.55	100.26
42	Grand Rapids.	Wood.........	Scott & Alexandar................	6.47	67.50	19.23	2.60	......	.83	0.48	2.50	......	$SO_3$0.26	100.27
43	Green Bay.....	Brown........	Green Bay Brick Co	13.02	48.39	12.50	5.40	10.88	4.82	0.68	3.90	0.43	Trace.	100.02

TABLE No. I.— *Chemical analyses of Wisconsin clays*—Continued.

No.	Location.		Name of Factory.	H_2O, C.	SiO_2.	Al_2O_3.	Fe_2O_3.	CaO.	MgO.	Na_2O.	K_2O.	TiO_2.	MnO.	Total.
	City.	County.												
44	Green Bay.....	Brown........	Green Bay Brick Co	17.34	44.18	10.83	3.30	14.05	5.91	0.70	3.10	0 30	....	99.75
45	Green Bay.....	Brown........	The William Finnegan Brick Co..	18.13	43.42	10.78	3.60	13.68	5.92	0.88	3.20	0.40	Trace.	100.01
46	Green Bay. ...	Brown........	The William Finnegan Brick Co..	8.15	59.98	16.33	7.10	1.02	1.97	1.04	4.22	0.58	....	100.39
47	Hersey	St. Croix	Undeveloped.....................	10.23	58.95	29.56	0.43	......	0.12	0.32	0.31	......	Trace.	99.98
48	Hersey	St. Croix.....	Superior China Clay Co........... (unwashed.)	8.90	64.50	26.20	0.07	......	......	......	0.31	......	....	99.98
49	Hersey	St. Croix.....	Superior China Clay Co........... (washed.)	11.89	52.41	34.10	0.15	0.05	0.12	0.18	0.46	0.80	....	100.16
*50	Horicon........	Dodge	J. M. Pluck	21.37	36.65	8.39	3.20	16 68	9.93	0.60	2.61	0.44	....	99.87
*51	Horicon........	Dodge	J. M. Pluck	4.60	74.12	11.78	4.50	0.96	0.85	0.44	2.62	0.56	....	100.43
*52	Hubbleton.....	Jefferson	Undeveloped.....................	16.33	46.69	12.48	3.60	10.28	6.57	0.41	3.01	0.67	Trace.	100.04
*53	Janesville.....	Rock	Undeveloped.....................	4.99	73.81	12.72	3.40	0.52	0.81	0.76	2.22	0.30		99.73
54	Junction City..	Portage	Graphite Works .... { C / H_2O	13.87 / 10.53	34.29	13.53	16.73	0.47	5.66	0.15	1.32	1.12	Volatile. 1.97	99.63
55	Kaukauna	Outagamie...	Lindaur & Rhode................	18.00	42 50	12.07	3.90	12.72	7.23	0 56	3.06	0.38	....	100.42
56	Kaukauna	Outagamie...	Lindaur & Rhode................	13 42	47.52	14.35	5.60	8.51	5.66	0.58	3.44	0.45	....	99.53
*57	Marengo	Ashland	Edward Hartman.................	13.22	47.66	14.98	6.00	10.27	4.14	0.74	2.18	0.56	0.25	100.00
58	Marshfield.. .	Wood.........	Central Wisconsin Pressed Br'k Co	6.55	68.74	10.65	3.16	3 81	2.73	1.94	2.06	0.43	0.14	100.21
59	Marshfield.....	Wood.........	Central Wisconsin Pressed Br'k Co	3.95	74.16	11.75	2.80	1.31	1.17	2.18	2.22	0.50	0.27	100 31
60	Marshfield.....	Wood.........	Central Wisconsin Pressed Br'k Co	4.29	73.29	11 98	3.32	1.34	1.09	1.92	2.10	0.55	0.14	100.00
61	Menomonie	Dunn	Wisconsin Red Pressed Brick Co.	4.69	65.44	13.51	5.40	2.95	2.20	1.54	3.44	0.60	Trace.	99.77
62	Menomonie	Dunn	Wisconsin Red Pressed Brick Co.	6.19	64.50	13.11	5.80	2.69	1.91	1.22	4.12	0.50	Trace.	100.04

63	Menomonie	Dunn	Wisconsin Red Pressed Brick Co.	6.79	63.36	14.01	6.40	2.63	2.21	1.02	3.48	0.50	Trace.	100.39
64	Merrillan	Jackson	Undeveloped......................	4.15	62.59	17.42	5.88	None	1.24	0.52	8.08	0.30	Trace of SO_3.	100.18
65	Merrillan	Jackson	Undeveloped......................	4.97	62.97	18.42	3.36	None	1.03	0.56	8.68	0.35	Trace of SO_3.	100.34
*66	Milwaukee.....	Milwaukee ...	Burnham Bros., Howell Ave. Yard	21.37	40.17	9.14	3.00	14.49	8.34	0.34	3.06	0.35	0.09	100.35
*67	Milwaukee.....	Milwaukee ...	Burnham Bros., West Yard........	20.08	41.63	8.51	3.40	14.39	8.02	0.54	2.90	0.35	0.23	100.05
*68	Milwaukee.....	Milwaukee ...	Standard Brick Co	19.79	43.84	7.82	2.00	15.16	8.03	0.62	2.44	0.33	....	100.03
69	Oakfield	Fond du Lac.	Frenzel Brothers	22.06	35.93	11.75	4.08	12.43	9.92	1.24	2.46	0.30	0.10	100.27
70	Oakfield	Fond du Lac.	Frenzel Brothers	25.17	31.70	9.19	3.76	15.37	10.90	0.68	2.74	0.25	0.27	100.03
71	Oshkosh ...... (7 miles west.)	Winnebago...	J. W. Schultz (Undeveloped)	19.23	39.11	11.98	5.57	15.45	4.67	0.97	3.08	.....	0.06	100.15
72	Oshkosh	Winnebago...	J. W. Schultz (Undeveloped)	14.79	47.30	12.42	5.36	9.46	6.22	1.35	3.17	......	0.19	100.26
73	Platteville.....	Grant.........	John Grindell.....................	6.98	70.48	13.26	4.20	0.81	1.11	1.18	1.84	0.50	Trace.	100.36
74	Platteville.....	Grant.........	John Grindell....	5.93	70.79	12.87	4.50	0.98	0.88	1.52	2.26	0.50	Trace.	100.23
75	Portage........	Columbia	A. P. Drinker	20.79	43.32	6.80	1.28	15.50	9.62	0.98	1.64	0.22	....	100.15
76	Portage........	Columbia	A. P. Drinker	23.06	38.06	8.71	1.20	16.28	9.96	0.72	1 56	0.26	... .	99 81
77	Port Wash'gt'n	Ozaukee......	Gottlieb Gunther & Sons.........	20.90	38.54	10.94	3.60	14.02	7.88	1.00	2.80	0.40	Trace.	100.08
78	Racine	Racine	Hilker Bros. Brick Mfg. Co........	20.44	39.97	9.99	2.80	16.05	7.74	0.70	2.60	0.28	....	100.57
79	Racine.........	Racine	Hilker Bros. Brick Mfg. Co........	15.73	52.25	9.42	2.50	10.60	6.70	0.88	2.26	0.28	Trace.	100.62
80	Rice Lake	Barron	Undeveloped......................	13.00	50.76	31.05	1.14	.60	......	0.01	0.24	......	....	99.80
81	Ringle	Marathon .. .	Clay Lumber Co...................	6.86	52.60	14.42	16.00	0.65	3.15	0.36	4.90	0.80	0.47	100.23
82	Ringle	Marathon	Clay Lumber Co...	6.00	54.47	13.68	15.96	0.55	3.17	0.40	4.60	1.10	0.33	100.26
83	Rinlge	Marathon	Clay Lumber Co...	6.14	49.29	13.03	20.20	0.31	4.15	0.40	5.72	0.85	0.21	100 30
*84	River Falls....	Pierce	River Falls Brick Co	6.72	62.74	17.01	5.60	2.38	1.84	0.34	3.18	0.60	....	100.41
*85	River Falls....	Pierce	River Falls Brick Co	4.50	70.02	14.77	5 00	1.02	1.03	0.60	2.73	0.62	....	100.29
86	Shawano.......	Shawano	Shawano Brick & Tile Co	16.31	45.78	9.39	3.80	14.86	5.85	0.66	3.02	0.40	Trace.	100.07

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TABLE No. I.— *Chemical analyses of Wisconsin clays* — Continued.

No.	Location. City.	Location. County.	Name of Factory.	H_2O, C.	SiO_2.	Al_2O_3	Fe_2O_3.	CaO.	MgO.	Na_2O.	K_2O.	TiO_2.	MnO.	Total.
87	Shawano.......	Shawano	Shawano Brick & Tile Co	17.29	43.56	11.12	3.60	15.12	5.61	0.58	3.28	0.40	Trace.	100.56
88	Sheboygan.....	Sheboygan ...	Sheboygan Brick & Tile Co	22.43	36.93	8.76	3.10	16.73	8.69	0.96	2.31	0.30	....	100.24
89	Sheboygan.....	Sheboygan ...	August Zimbal & Son	22 29	38.92	7.50	2.36	15.92	9.82	0.86	2.00	0.25	Trace.	99.92
90	Sheboygan.....	Sheboygan ...	August Zimbal & Son.............	22.82	37.86	7.12	3.64	16.42	9.56	0.86	1.90	0.20	Trace.	100.38
91	Sheboygan....	Sheboygan ...	August Zimbal & Son.............	21.88	36.80	9.43	3.00	16.38	8.78	0.94	2.36	0.23	Trace.	99.80
92	Shiocton.......	Outagamie...	W. D. Jordon (undeveloped)......	17.48	43.99	10 06	3.84	14.47	5.72	1.06	3.18	0.33	0.18	100.31
93	Springfield.....	Walworth	Springfield Brick & Tile Co.......	5.81	70 15	13.98	4.80	1.18	1.03	1.34	1.94	0.36	....	100.59
94	Springfield.....	Walworth	Springfield Brick & Tile Co.......	3.78	75 58	12.18	3.30	1.01	0.84	1.08	2.04	0.38	....	100.19
95	Superior	Douglas......	Undeveloped..........	6.18	58.19	18.77	7.90	0.59	3.92	0.10	3.78	0.55	Strong trace.	99.98
96	Tomah	Monroe.......	Tomah Brick Yard	2.59	78.37	11.61	3.22	0.94	0.34	.69	1.07	......	....	99.83
*97	Tomahawk	Lincoln	Tomahawk Brick Yard...........	3.37	70.41	13.64	5.20	1.54	1.49	1.44	2.68	0.41	Trace.	100.18
*98	Tomahawk	Lincoln	Tomahawk Brick Yard...........	4.33	69.46	14.71	4.60	1.21	1.56	1.26	3.00	0.41	Trace.	100.5
99	Viroqua........	Vernon	Viroqua Brick Yard..............	5.30	74 71	12.60	2.80	0.70	0.55	1.14	2.18	0.55	Strong trace.	100.53
100	Viroqua........	Vernon	Viroqua Brick Yard	3.12	78.26	11.41	1.80	1.00	0.68	1.28	1.88	0.45	....	99.88
101	Watertown	Jefferson and Dodge.	L. H. Cordes & Co................	25.19	31.90	8.74	3.00	17.06	10.63	0.82	2.20	0.25	0.19	99.98
102	Whittlesey.....	Taylor........	Langenberg Brick Co............	4.40	69.86	13.55	5.46	0.71	1.43	1.78	2.36	0.77	Trace.	100.32
103	Whittlesey.....	Taylor........	Langenberg Brick Co.............	4.10	70.51	13.60	4.48	0.70	1.41	1.94	2.36	1.00	.. ..	100.13
104	Wind Lake....	Racine	Wind Lake Brick & Tile Co.......	18.03	44.09	11.87	4.00	10.29	7.15	0.86	2.74	0.75	....	99.78
105	Wonewoc	Juneau	Wonewoc Red Pressed Brick Co..	4.37	74.91	12.28	3.20	0.72	0.63	1.20	2.28	0.40	Trace.	99.99
106	Wonewoc	Juneau	Wonewoc Red Pressed Brick Co..	5.35	73.66	12.72	3.50	0.69	0.83	1.06	2.38	0.35	....	100.54

TABLE No. II.— *Rational analyses and Bishof's refractory quotient.*

Number corresponding with number in Table I.	Total fluxes.	Free SiO_2 and SiO_2 as other silicates than feldspar and kaolin.	Feldspathic matter.	Kaolinite base.	Oxygen ratio SiO_2 to Al_2O_3	Oxygen ratio. Alumina to 3.0 in RO. All Fe calculated as FeO.	Bishof's refractory quotient.
1	11.31	29.58	22.88	36.76	3.706	1.152	.311
2	24.78	31.10	17.51	14.43	6.198	.188	.030
3	8.25	48.35	22.43	21.80	6.451	1.104	.07
4	25.08	31.20	16.08	15.80	6.008	.193	.032
5	6.31	38.67	23.84	34.30	4.404	.201	.457
6	17.72	27.13	26.46	33.29	3.732	0.691	.186
7	23.95	19.06	23.02	34.45	3.162	0.456	.144
8	7.74	38.53	34.34	24.56	5.079	1.453	.286
9	18.23	21.56	25.97	37.42	3.216	.704	.219
10	13.03	35.02	26.08	29.09	4.526	.784	.173
11	11.20	31.36	37.57	26.13	4.445	1.059	.238
12	15.21	29.88	31.55	20.38	4.940	.587	.119
13	35.45	13.99	16.18	10.30	4.676	.101	.021
14	34.71	13.18	16.55	12.38	4.207	.116	.028
17	24.55	15.79	25.30	24.51	3.429	.331	.097
18	30.34	14.20	19.35	19.22	3.610	.198	.055
19	9.50	45.55	23.79	22.41	5.893	.960	.163
20	9.61	50.03	23.00	18.79	7.128	.857	.120
21	12.05	40.41	31.25	17.80	6.066	.739	.122
22	27.39	53.35	24.23	9.99	6.232	.169	.027
23	14.35	34.85	29.77	20.99	5.225	.616	.118
24	17.47	28.88	33.92	19.29	4.859	.516	.106
25	19.81	32.02	28.12	18.05	5.363	.404	.075
26	15.39	29.38	30.21	25.09	4.416	.639	.145
27	8.70	49.59	31.07	16.02	7.003	.984	.141
28	13.15	2.08	35.77	52.61	2.052	1.450	.706
29	16.00	13.94	41.29	35.40	2.989	.926	.310
30	20.54	7.36	46.18	30.26	2.835	.666	.235
31	4.26	2.66	6.42	86.20	1.504	6.065	4.033
32	44.99	35.46	8.54	1.31	2.100	.037	.002
33	23.[illegible]	27.27	21.74	17.12	5.159	.248	.048
34	24.56	26.22	20.54	16.81	5.116	.229	.045
35	31.00	16.39	18.70	16.73	4.065	.170	.042

TABLE No. II.—*Rational analyses and Bishof's refractory quotient*—Continued.

Number corresponding with number in Table I.	Total fluxes.	Free SiO_2 and SiO_2 as other silicates than feldspar and kaolin.	Feldspathic matter.	Kaolinite base.	Oxygen ratio SiO_2 to Al_2O_3	Oxygen ratio. Alumina to 3.0 in RO. All Fe calculated as FeO.	Bishof's refractory quotient.
36	32.34	14.10	18.75	13.75	4.222	.144	.034
37	32.93	13.20	20.90	12.15	4.221	.138	.033
39	0.66	34.22	2.66	62.91	2.903	33.054	11.362
40	27.27	20.49	35.54	19.19	4.187	.268	.064
41	38.99	8.32	13.35	37.44	2.251	.269	.120
42	6.56	36.34	18.87	40.41	3.909	2.132	.545
43	25.68	21.11	28.84	18.05	4.368	.282	.065
44	27.06	20.82	24.29	15.93	4.602	.219	.048
45	27.28	19.17	26.39	14.79	4.544	.218	.048
46	15.35	26.20	33.79	24.86	4.195	.726	.173
47	1.18	22.13	4.55	72.63	2.250	17.137	7.617
48	0.38	32.87	1.84	65.47	2.777	68.350	24.610
49	0.96	10.40	4.25	84.30	1.734	23.207	13.383
54	24.82	14.42	9.09	29.98	2.859	.290	.101
55	27.47	18.34	22.85	19.77	3.973	.238	.060
56	23.79	19.61	25.27	24.43	3.736	.363	.097
58	13.84	43.44	28.63	13.16	7.282	.452	.062
59	9.95	46.22	31.61	14.51	7.121	.766	.108
60	9.91	46.39	28.70	16.51	6.902	.795	.115
61	15.53	34.80	33.41	18.28	5.465	.561	.103
62	15.74	33.85	34.71	16.73	5.551	.555	.100
63	15.74	34.06	29.24	21.59	5.102	.583	.114
64	15.72	19.52	52.22	19.62	4.056	.860	.212
65	13.63	17.01	56.11	20.36	3.857	1.223	.317
69	30.23	11.03	25.07	17.77	3.450	.203	.059
70	33.72	11.27	21.98	12.86	3.892	.141	.036
71	29.80	13.41	26.45	17.77	3.683	.230	.062
72	25.75	19.37	30.20	17.06	4.297	.271	.063
73	9.14	45.44	21.05	23.57	5.997	.979	.167
74	10.14	43.99	26.25	20.00	6.205	.876	.141
75	29.02	27.35	18.01	8.58	7.187	.118	.016
76	29.72	21.05	15.33	14.73	4.930	.146	.030

TABLE NO. II.—*Rational analyses and Bishof's refractory quotient*—Continued.

Number corresponding with number in Table I.	Total fluxes.	Free SiO_2 and SiO_2 as other silicates than feldspar and kaolin.	Feldspathic matter.	Kaolinite base.	Oxygen ratio SiO_2 to Al_2O_3	Oxygen ratio. Alumina to 3 0 in RO. All Fe calculated as FeO.	Bishof's refractory quotient.
77	29.30	14.65	25.04	15.87	3.975	.199	.050
78	24.89	18.88	21.32	15.19	4.514	.177	.039
79	22.94	31.99	20.84	13.93	6.259	0.217	.035
80	1.99	1.73	9.77	85.52	1.684	12.114	7.203
81	25.55	21.75	32.05	21.48	4.4115	.398	.097
82	25.01	25.10	30.61	20.38	4.492	.385	.086
83	30.99	17.83	27.24	15.55	4.268	.296	.069
86	28.19	24.48	23.46	12.69	5.501	.184	.033
87	28.09	19.86	24.33	16.69	4.420	.218	.049
88	31.82	16.39	21.98	11.72	4.687	.145	.031
89	29.96	21.67	19.12	9.87	5.855	.129	.022
90	32.38	21.31	18.37	9.19	5.999	.114	.019
91	31.46	16.09	21.88	13.45	4.403	.157	.036
92	28.45	20.08	27.65	12.28	4.933	.196	.040
93	10.29	43.56	22.84	24.43	2.661	.916	.162
94	8.27	51.86	21.23	20.69	7.001	.998	.143
95	16.29	26.09	23.33	36.66	3.498	.738	.211
99	7.37	49.89	22.56	21.14	6.690	1.203	.180
100	6.64	55.07	21.97	18.36	7.738	1.138	.147
101	33.90	12.83	19.97	12.63	4.127	.133	.032
102	11.74	40.99	29.05	20.36	5.817	.780	.134
103	10.89	41.00	30.41	19.91	5,852	.832	.142
104	25.04	19.59	23.50	19.12	4.191	.256	.061
105	8.03	50.28	23.36	19.80	6.882	1.068	.155
106	8.46	48.51	23.06	21.22	6.533	1.048	.160

TABLE No III.—*Analyses of typical*

Location.		Titanic acid, TiO_2.	Silica, SiO_2.	Alumina, Al_2O_3.	Combined water H_2O.	Moisture, H_2O.	Iron sesquioxide Fe_2O_3.	Lime, Ca O.	Magnesia, MgO.
									VITRIFIED OR
Arkansas, Fort Smith, shale....		.....	58.43	22.50	6.20	.....	8.35	......	1.14
Georgia, Cartersville, residual clay....		... ..	58.63	20.47	7.06	0.20	8.58	T'ce	1.42
Illinois, Galesburg, shale....		... ..	68.69	17.95	.....	.....	7.25	0.76	1.47
Illinois, Streator, shale..		... ..	61.76	18.32	7.94	......	2.04	......	1.45
Indiana, Clinton, shale.....		.. ..	43.13	40.87	9.48	......	3.44	2.01	0.97
Iowa, Des Moines, shale...		.....	60 34	24.26	1.66	......	7.73	1.35	0.70
Kentucky, Robbins, shale.............		......	70.57	15.19	.....	......	7.97	0.78	0.32
Kentucky, Butler county, shale......		......	51.66	15.56	13.44	......	7.68	7.27	0.82
New York, Howelsville.		.....	64.45	17.77	. ...	......	7.04	0.58	1.85
Ohio, Canton, shale....		.....	57.10	21.29	6.00	1.30	7.31	0 20	1.58
Ohio, Independence, shale.......... .		.....	57.40	21.20	7.75	.....	6.57	1.00	1.40
									FIRE
Alabama.........	Choctaw County....	.. ..	83.30	5.12	0.60	......	1.60	0.46	......
Colorado.........	Golden	......	46.88	35.42	14.10	......	1.74	0.44	0.20
Colorado.	Morrison......... ..	......	71.80	15.00	8.30	.....	T'ce	3.80	.. ...
Illinois..........	Utica	1.15	56.65	26.45	9.80	2 10	2.10	... .	0.80
Kentucky.	Gormon, Carter Co.	.....	49.75	35.16	14.03	. ....	0.30	0.54	0.15
Maryland	Mt. Savage..........	......	50.46	35.91	12.78	......	1.51	0.13	1.02
Maryland	Mt. Savage.	.. ..	55.75	33.23	10.37	......	....	2.06	......
New Jersey.....	Woodbridge	......	54.90	31.66	10.50	0.60	0.74	......	......
New Jersey.....	Bonhampton........	1.60	75.25	15.50	4.90	1.30	1.20	. .....	.. ..
Ohio............	Gaylord, Scioto Co..	.. ...	44.34	40.05	14.23	......	0.80	0.27	T'ce
Ohio............	Salineville	.. ..	59.92	27.56	9.70	1.12	1.03	T'ce	T'ce
Pennsylvania.....	Johnstown..........	1.55	45.25	38.84	12.50	0.70	0.91	......	......
Pennsylvania.....	Clinton.......	1.46	63.18	23.70	6.87	.. ..	1.20	0.17	0.47
Pennsylvania.....	Woodland Mine. ...	.....	45.29	40.07	13.18	......	1.02	0.26	0.08

clays outside of Wisconsin.

PAVING BRICK.

Potash, K_2O.	Soda, Na_2O.	Miscellaneous.	Total impurities.	Grand total.	Age.	Authority.
2.18	1.03	S. 1.16	13.86	100.99	Coal Meas	Brickmaker, Vol. XIII, No. 3, Chicago.
3.86	0.14	....	14.00	100.36	Paleozoic........	Georgia Geol. Surv., Geology of Paleozoic, Spencer, 1899.
2.83	......	1.05	12.31	100.00	Coal Meas......	Clay Worker, April, 1895 (Meade), Indianapolis.
3.49	......	....	11.98	100.00	Coal Meas.	As above.
0.02	......	......	6.44	99.92	Coal Meas.......	As above.
3.12	......	....	12.90	99.16	Coal Meas.......	As above.
1.15	......	....	10.22	100.00	Coal Meas.	As above.
3.57	......	....	19.32	99.98	Coal Meas.......	As above.
2.52	1.95	....	13.94	96.16	Devonian.......	Clay Industries of N. Y., Ries, Albany, 1895.
3.44	0.61	....	13.18	98.87	Coal Meas......	Clay Worker, May, 1894, Orton, Indianapolis.
4.10	1.00	....	14.07	100.42	Coal Meas.......	Clay Worker, May, 1894, Orton, Indianapolis.

BRICK.

Potash, K_2O.	Soda, Na_2O.	Miscellaneous.	Total impurities.	Grand total.	Age.	Authority.
......	......	....	2.06	100.08	Tertiary	Ala. Industrial and Scien. Soc., Proc., Vol. I.
1.19	......	....	3.57	99.77	Cretaceous......	Tables of Analyses of calys, Crossley, Indianapolis, 1889.
......	.....	....	3.80	98.90	Cretaceous......	U. S. Geol. Survey, Mineral Resources for 1892.
1.10	......	....	3.50	99.65	Coal Meas.......	N. J. Geol. Survey, Report on Clays, Cook, Trenton, 1878.
0.07	......	....	1.06	100.00	Coal Meas.	Tables of Analyses of Clays, Crossley, Indianapolis, 1889.
T'ce	......	....	1.64	100.79	Coal Meas.......	Brickmaker, Vol. XIII, No. 3, Chicago.
......	......	....	2.06	101.41	Coal Meas.......	Brickmaker, Vol. XIII, No. 3, Chicago.
1.53	......	......	2.27	99.93	Creta. (Woodbridge bed)...	N. J. Geol. Surv., Report on Clays, Cook, Trenton, 1878.
0.17	......	....	1.37	99.92	Creta. (Woodbridge bed)....	N. J. Geol. Surv., Report on Clays, Cook, Trenton, 1878.
T'ce.	T'ce.	....	1.07	99.79	Coal Meas.......	Clay Worker, August, 1895, (Orton) Indianapolis.
0.67	......	....	1.70	100.00	Coal Meas.......	Clay Worker, August, 1895., (Orton) Indianapolis.
0.35	......	....	1.26	100.10	Coal Meas.......	N. J. Geol. Surv., Report on Clays, Cook, Trenton, 1878.
2.52	......	SO_3 0.19	4.55	99.76	Coal Meas.......	Penn. Geol. Survey, Vol. L.
0.05	......	....	1.46	100.00	Coal Meas (calcined)...	Tables of Analyses of Clays, Crossley, Indianapolis, 1889.

TABLE No. III—*Analyses of typical*

Location.		Titanic acid, TiO_2.	Silica, SiO_2.	Alumina, Al_2O_3.	Combined water H_2O.	Moisture H_2O.	Iron sesquioxide Fe_2O_3.	Lime, CaO.	Magnesia, MgO.
									SEWER
New Jersey......	Woodbridge	1.00	67.70	19 91	5.50	1.00	1.69	.....	0 72
New York... ...	Angola	......	65.15	15.29	....	......	6 16	3.50	1.57
Ohio..............	Walker Station.....	1.26	54.53	27.88	8.87	0.76	2 41	0.44	0.68
Ohio..	Columbus...	......	58.38	20.89	7.53	......	5.78	0.44	1.57
									DRAIN
Ohio.....	Waynesburg.	0 16	68.89	15.89	7.07	1.03	2.86	0.55	0.66
									TERRA
New York........	Elm Point	......	62.06	18.09	.....	......	5.40	1 05	T'ce
									SAG
Ohio.........	Liverpool...........	1.20	60 30	24.12	7.77	0.86	1.46	0.59	0.68
									BUFF
New York	Canandaigua.......	......	46.55	12 66	0 90	.....	4.92	14.02	4.67
									ORNAMENTAL
New Jersey......	Sayreville...	1.00	56.10	27.42	6 60	2.90	2.68	.....	0.18
									WHITE
Alabama.........	Talledega...........	.. ...	43 21	37.27	18.50	......	T'ce	0.11	0.10
Delaware....,....	Hokessin	....	47.20	34.10	12.35	1.35	2 49	......	0.39
Pennsylvania	BrandywineSummit	... ..	46.28	36.25	13.54	......	1.64	0.19	0.32

clays outside of Wisconsin — Continued.

Potash, K_2O.	Soda, Na_2O.	Miscellaneous	Total impurities	Grand total.	Age.	Authority.
PIPE.						
7.56	......	....	4.97	100.08	Cretaceous (Wood bridge bed)	N. J. Geol. Surv., Report on Clays, Cook, Trenton, 1878.
5.71	......	....	16.94	97.38	Devonian.. . ..	Clay Industries of N. Y., Ries, Albany, 1895.
3.31	0.12	... .	6.94	99.54	Coal Meas.	Ohio Geol. Surv., Economic Geol. E. Orton, Jr., Columbus, 1884.
4.68	0 34	....	11.91	99.61	... ...	Clay Worker, May, 1894, (Orton), Indianapolis.
TILE.						
2.23	0.29	....	6.61	99.65	Coal Meas.......	Ohio Geol. Survey. Vol. V., Economic Geol.. E. Orton, Jr., Columbus. 1884
COTTA.						
6.11	......	....	12.56	92.71	....	Clay Industries of N. Y., Ries, Albany, 1895.
GERS.						
2.42	T'ce.	....	4.95	99.40	Coal Meas.......	Ohio Geol. Survey. Vol. V., Economic Geol. E. Orton, Jr., Columbus, 1884.
BRICK.						
2 05	......	CO_2 14.62	25.66	100.37	Glacial.........	
BRICK.						
2.71	. ....	....	5.57	99.57	Cretaceous......	N. J. Geol. Surv., Report on Clays, Cook, Trenton, 1878.
WARE.						
0.68	......	....	0.89	99.87	....	Mineral Industry, Vol. II. for 1893, New York, 1894.
1.64	0.27	....	3.79	99.81	From Granite...	N. J. Geol Surv., Report on Clays, Cook, Trenton, 1878.
2.53	......	....	4 68	100.75	... .	Mineral Industry, Vol. II. for 1893, New York, 1894.

TABLE NO. III.—*Analyses of typical*

Location.		Titanic acid, TiO_2.	Silica, SiO_2.	Alumina, Al_2O_3.	Combined water H_2O.	Moisture, H_2O.	Iron sesquioxide Fe_2O_3.	Lime, Ca O.	Magnesia, MgO,
									STONE
New York......	Kreischerville	......	64.26	24.76	.. ..	.....	0.83	0.73	T'ce
New York	Little Neck.........	......	62.26	17.09	......	.....	0.97	0.79	......
Ohio.............	Roseville	0.35	63.40	23.01	8.03	0 97	1.50	0.41	0.62
									NOT
Alabama.........	Jacksonville	. . ..	44.60	38 92	13.35	.....	0.78	......	1.03
Arkansas....	Poinsett County....	......	61.76	22.91	8.75	.... .	3.32	0.75	0.90
California	Carbondale	......	57.02	31.06	8.95	......	0.53	. ....	......
California.... ...	Carbondale.........	.....	48.90	33.18	8.65	......	2.40	0.50	0.09
California........	Chico....	......	88.70	4.50	4.46	.. ..	0.50	0.93	0.36
Washington......	Mackintosh bed.....	......	69.71	18.39	8.94	.. ..	1.44	0.35	0.15

clays outside of Wisconsin — Continued.

Potash, K_2O.	Soda, Na_2O.	Miscellaneous.	Total impurities.	Grand total.	Age.	Authority.
WARE.						
2.35	......	....	3.91	92.93	Cretaceous......	Clay Industries of N. Y., Ries, Albany, 1895.
2.23	......	....	3.90	84.74	....	Clay Industries of N. Y., Ries, Albany, 1895.
1.26	T'ce.	....	3.79	99.55	....	Tables of Analyses of Clay, Crossley, Indianapolis, 1889.
CLASSIFIED.						
......	......	....	2.71	99.58	Cambrian.......	Transactions American Inst. of Mining Engineers, Vol. X.
0.62	0.38	....	5.97	99.39	Tertiary	Ark. Geol. Survey, Annual Report, Vol. 1, 1889.
2.32	......	....	2.85	99.88	....	Calif. State Mineralogist, 9th Report, Irelan, Sacramento, 1889.
1.85	......	....	2 99	98.72	....	Calif. State Mineralogist, 9th Report, Irelan, Sacramento, 1889.
0.63	......	....	2.42	100.08	....	Calif. State Mineralogist, 9th Report, Irelan, Sacramento.
0.19	0.83	....	2.96	100.00	Fuses 283 ...	Wash. Geol. Survey, 2nd Annual Report, Tacoma.

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